

THE RISE OF EARLY ROME

*Transportation Networks and Domination
in Central Italy, 1050–500 BC*

FRANCESCA FULMINANTE



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The trajectory of Rome from a small village in Latium vetus, to an emerging power in Italy during the first millennium BC, and finally the heart of an empire that sprawled throughout the Mediterranean and much of Europe until the 5th century CE is well known. Its rise is often presented as inevitable and unstoppable. Yet the factors that contributed to Rome's rise to power are not well understood. Why Rome and not Veii? In this book, Francesca Fulminante offers a fresh approach to this question through the use of a range of methods. Adopting quantitative analyses and a novel network perspective, she focuses on transportation systems in Etruria and Latium Italy in *ca.* 1000–500 BC. Fulminante reveals the multiple factors that contributed to the emergence and dominance of Rome within these regional networks, and their critical role in the rise of the city and, ultimately, Roman imperialism.

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Introduction

Urbanism in the past and present remains hotly debated in academia and the media (we could mention the Copenhagen Polis Centre project; the Reception of the City in Late Antiquity European Research Council project, Cambridge; the UrbNet project, Aarhus; the Social Reactors Project, Colorado; the OIKOS Dutch network; and the Cities series published by the Guardian in the UK media). What is an ancient city? When can we say that a nucleated settlement has become a city? Why does a city sometime prevail over others and why does it eventually decline? These questions are matters for lively debate that have not yet been answered definitively, especially with reference to central Italy and Rome in particular. The long-term trajectory of Rome is quite well known and established from the early supremacy within Latium vetus in pre-historic and early historic times, to the emerging power in Italy, during the Republican period, and finally the dominance over the Empire, in the first few centuries of the last millennium before the final collapse around the end of the fourth century AD.

My earlier work on the urbanisation of Rome and Latium vetus, published by Cambridge University Press in 2014,¹ showed that during the Bronze Age and the beginning of the Early Iron Age, Rome was just a small village like many others in the region, admittedly one of the larger settlements but by no mean the largest of all. It was only during an advanced part of the earlier phase of the Early Iron Age (Latial Period IIA2–IIB) that Rome grew to become a large unified proto-urban centre of about 202 ha comparable in size only to other major Etruscan settlements and absolutely the largest and most populous in Latium vetus by a considerable degree.² Previously, my colleagues and I suggested that this imbalance of power might be one of the keys to Rome's success,³ but only a comprehensive comparison between Latium vetus and Etruria might identify

similarities and/or differences between these two regions and ultimately answer the burning question: Why Rome and not Veii? What gave the Eternal City its ultimate advantage and made it possible for her to supersede all equal powers in central Italy and therefore dominate the region and eventually all the known world?

In this book, I focus on transportation networks (or fluvial and terrestrial transportation infrastructures) in central Italy between the Final Bronze Age and the Archaic Period (1050–500 BC *ca.*), as a way to analyse and compare quantitatively and formally the two different socio-political and economic systems of southern Etruria and Latium vetus, so similar yet so different and destined to such divergent outcomes with the dominance of Rome and Latium vetus and the defeat of southern Etruria. Means of transport are essential for permitting inter-settlement cooperative processes (information exchange, trade, defence, etc.) and influence the development of past societies and their complexification.⁴ In order to be established and be used, transportation infrastructures (especially terrestrial routes) need some level of cooperation among neighbouring polities. In addition, since their maintenance requires a not negligible amount of resources, they are affected by competing interests. More generally, transportation infrastructures can be regarded as a product of social interactions and interactions between societies and environments. The geographical system of transportation and the social system of interactions are tightly connected by a permanent interplay (Fig. 1.1).⁵ We can think of each connection between a pair of places as the result of a negotiation that involves the two actors but that can also be influenced, to some extent, by ‘third parties’ as, for instance, a political authority acting on a higher level.

Actor network theory⁶ and assemblage theory⁷ provide the theoretical background, while network science and geographical information systems (GIS) provide the methodology and the tools to develop the argument of this book. Therefore, to better understand emerging Latin and Etruscan urban polities and the mechanism underlying the success of one of them and the decline of the other this book analyses fluvial and terrestrial communication networks with both traditional and the most up-to-date network science techniques. The calculation of traditional centrality indexes, the application of efficiency measures, the application of a multi-scale perspective and modelling through the most advanced mathematical methods will show how the Latin and Etruscan systems worked and suggest why possibly Rome in the end prevailed over the rival Veii.

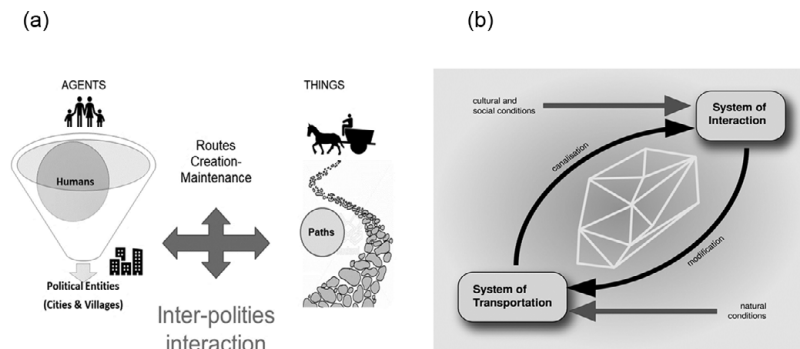


FIGURE 1.1. (a) Relationship between human/agents (grouped into polities), routes/paths and activities. (b) Interrelationship between transportation infrastructures and system of interaction. (From Fulminante 2020c)

The first chapter of the book will revisit the current debate on the still unresolved problem of the definition of the ‘ancient city’.⁸ While there are cultural differences and regional variations in the form a city can take in different parts of the ancient and modern world, there are still some repeating patterns in their size, density, relation to the countryside, and political, social, economic and religious organisation. Many studies have analysed these variables for many regions and chronological periods in the world, as well as from a comparative perspective.⁹ With reference to central Italy, all these dimensions have been analysed by many scholars and were re-assessed in my previous book on the urbanisation of Rome and Latium vetus.¹⁰ A new perspective recently added to the debate in this area is the comparison between the two neighbouring but also very different regions of southern Etruria and Latium vetus. While in the past the two regions have been generally studied separately, as being the object of different fields of research, respectively Etruscology and pre/protohistorical archaeology, some recent research has started comparing them with each other and has shown their similar developments yet contrasting trajectories.¹¹ As is well-known, with the defeat of Veii (496 BC), Rome established its supremacy and eventually fully prevailed over all Etruria incorporating its territory within the Roman polity.¹² By explaining how the Etruscan and the Latin systems worked through the analysis of their transportation systems, this book will try to explain the reasons of these different outcomes and of the success of Rome.

The second chapter will discuss the contribution of the network approach to the Archaeological discipline both as a conceptual frame (network as a metaphor) and as a formal tool of analysis (network as a

tool) also with reference to the debate on urbanism in the Mediterranean during the first millennium BC. As emphasised by Robin Osborne, the main characteristic of cities in the Mediterranean during the 1st millennium BC is their interest in and their connection to cities elsewhere.¹³ In this sense, the network model applied to urbanisation has proved successful at regional and supra-regional scales, both as a metaphor¹⁴ and as a tool of analysis.¹⁵ The network perspective has also been taken recently by the Danish-funded centre of excellence UrbNet which analyses urban networks in Europe from antiquity up to mediaeval times. The application of network analysis to archaeology has grown exponentially in the last few decades¹⁶ because of its capacity to see things, people and places, not as static entities with certain attributes, but as active, connected agents, in relation among themselves and to each other within an interrelated wider system.¹⁷ Transportation infrastructures are very suitable for the study of urbanism within a network approach because, as mentioned earlier, they are a product of social interactions and interactions between societies and their environments; and moreover, because they can be fruitfully translated into graphs suitable for quantitative and statistical analysis.¹⁸

Chapter 3 illustrates the data used and the methodology applied for the analyses. Data used are settlements (nodes) in Etruria and Latium vetus between the end of the Final Bronze Age and the end of the Archaic Period. Modern Lazio, corresponding to southern Etruria to the north of the Tiber and Latium vetus to the south of it, is a region very intensively studied since the tradition of the British grand tours of the 18th century, the antiquarian tradition of the 19th century and the more recent landscape and topographic traditions of the 1960s and 1970s. In addition, in the last few decades many important research projects have been conducted by Italian and/or international teams with modern standards and up-to-date methodologies that have greatly improved the knowledge of the region not only at key excavated sites but also broadly in the territory around them. Finally, in recent years, the work of Regione Lazio (regional Italian council) has revised all previous studies and produced the *Repertorio dei Siti Preistorici e Protostorici del Lazio*, a very special and useful tool to approach a large amount of data with a synthetic and highly detailed approach.

Fluvial connections were provided digitally by Regione Lazio. While terrestrial routes (links) were reconstructed from various hypotheses advanced by many scholars, collated among themselves and verified on later roads, topography and the position of existing settlements. Chapter 3 will describe how all this data have been collected and how the networks have been constructed and the methodologies applied to analyse them,

from traditional centrality indexes to more specific efficiency indexes to advanced modelling; including a discussion of issues and problems of applying network science technique to archaeological and historical data. While there are biases and problems in applying a network science approach to the past (such as heterogeneous and sometime missing or scarce data), general trends can still be securely identified and enrich our historical narrative if carefully interpreted.¹⁹

In Chapter 4, network analysis indexes will be applied. Firstly, traditional centrality indexes such as betweenness centrality, degree centrality and closeness centrality will be applied to southern Etruria and Latium vetus fluvial and terrestrial transportation routes. In this way, it will be possible to compare the importance of the different transport systems, fluvial and terrestrial, in the two regions and assess if there is any difference and/or similarity. As it will be shown in more detail in the chapter, the fluvial transportation communication routes seem to be more relevant in Latium vetus in the Bronze Age than the subsequent Early Iron Age when land transport becomes more prominent for the centrality of proto-urban and urban centres. Unfortunately, data on Final Bronze Age terrestrial transportation routes in southern Etruria are not yet available on a regional scale, but data for the Early Iron Age confirm the prominence of this mean of transport to predict the centrality of Etruscan centres. The Latin and Etruscan city-state polities will be considered as systems but also the centrality degree of single centres larger than 80 ha will be compared to one another to obtain a more detailed picture at the local scale (ego-network approach). When considering the potential of single proto-urban and urban Latin and Etruscan centres larger than 80 ha, Rome seems to have generally the highest score even if Gabii is also very prominent.

Secondly network science efficiency indexes such as the average strength (or average weighted degree), the global and local efficiency and the smallest positive value of the eigenvalue of the weighted Laplacian matrix or algebraic connectivity (L_w) will be applied and described in more detail in Chapter 5. As will be shown, comparing the efficiency of the Etruscan and Latin fluvial and terrestrial transportation systems, the Latin system generally appear to work better than the Etruscan system. The global efficiency (the general flow of goods and information in the system) is very advantageous for the fluvial system and slightly advantageous for the terrestrial system in Latium vetus. In contrast, the smallest positive value of the eigenvalue of the weighted Laplacian matrix or algebraic connectivity (L_w) value shows much better results for the terrestrial Latin system than the Etruscan and only slightly better for the Latin fluvial system. The gap in the local efficiency between Etruria and Latium vetus becomes less prominent for later

periods. Finally, the weighted degree shows a noticeable advantage for the Latin terrestrial transportation system. To conclude, while not all indexes agree, generally the Latin transportation system seems to work slightly better than the Etruscan transportation system and that might contribute to explaining the advantage of one region over the other.

In Chapter 6 some early work of a multi-scale approach based on least-cost-paths is presented. I am aware of the critique and problems raised about the application of least-cost-path analysis,²⁰ and at the beginning of our work we had decided not to adopt this methodology. It is undeniable that approached with caution this is a complementary technique that combined with network analysis promises to be very fruitful.²¹ In collaboration with various colleagues, we are just starting to move in that direction, but at this stage, we think it would be useful to complete the picture offered by network analysis by presenting some preliminary results of this complementary methodology. In this multi-scale analysis, we will look more specifically at pre-Roman and Roman transportation routes to better contextualise emerging Etruscan and Latin interaction networks based on use of occasional paths and understand their relationship to the later emergence of the dense Roman road networks.

Finally, in Chapter 7, I will present the results of some modelling conducted in collaboration with Spanish colleagues and presented already in previous work,²² in order to better understand emerging Latin and Etruscan urban polities. More specifically, in collaboration with some Spanish colleagues, we modelled terrestrial infrastructure networks in southern Etruria and Latium vetus to explore the underlying mechanism of their creation and maintenance. In our models, settlements behave as nodes/agents: they act on themselves and their environment and they communicate among themselves. Their behaviour is the result of their observation, their knowledge and their interaction with other agents. As per the other analyses, data used are settlements (nodes) in Etruria and Latium vetus between the beginning of the Early Iron Age and the end of the Archaic Period; and terrestrial routes (links) hypothesised by scholars based on later roads, topography and the position of existing settlements. More specifically we designed and applied to southern Etruria and Latium vetus different network models. Each model corresponds to a different hypothesis about the dominant mechanism underlying the creation of new connections. After locating the nodes at the positions inferred from the archaeological record, we started adding links according to a specific criterion. Once we had generated several synthetic versions of the networks, we compared them to the corresponding empirical system to

determine which model fitted the data better and therefore was more likely to resemble the actual forces at work. The results of the modelling suggested that a balanced coordinated decision-making process was shaping the route network in Etruria, whereas in Latium vetus a slightly unbalanced dynamics of power constitutes the most likely underlying mechanism. This fits very well with the picture elaborated by different scholars on the nature of power balance and dynamics in the two regions.

To conclude, this study of the transportation networks in Etruria and Latium vetus during the first half of the first millennium BC will provide insight into the interactions among these past cities and provide us with a new way to look at urbanism in a wider global perspective. In particular, the analysis of transportation networks in Etruria and Latium vetus by means of traditional network centrality indexes will show that terrestrial routes were more important than fluvial routes in shaping the centrality of primary centres during the Early Iron Age, and Orientalising and Archaic Periods, at least at a local intraregional level. The comparison between Etruria and Latium vetus by network efficiency indexes will show that the Latin transportation system generally performed better than the Etruscan system, and this might contribute to explain the advantage of this region over the rival.

As shown by some other research I have done on cultural networks²³ and by other scholars also from a network perspective,²⁴ the internal economic and cultural dynamics of the two regions were not so different after all. Finally, the different analyses presented in this work and particularly the modelling will suggest the real difference between Etruria and Latium might be sought in the different dynamics of power between the two regions: more balanced and equally distributed in Etruria and more unbalanced and dominated by the emergence of Rome in Latium vetus. Latium as a system was a more compact region, highly connected and with a stronger hierarchy that eventually had an advantage over the larger but more divisive and heterarchical Etruria.²⁵

CHAPTER 1

The Ancient City

Still a Debated Topic

1.1 The Ancient City: Is a Definition Possible?

Some years ago, the ‘Copenhagen Polis Centre’ project debated the essence of the ancient Greek city and produced an inventory of all ancient Greek cities in Archaic and Classical times, within a wider comparative perspective of emerging urban societies from different parts of the world and different chronological settings. More recently the ‘Reception of the City in Late Antiquity’ European Research Council funded project at the University of Cambridge, re-examined the impact of the ancient Greco-Roman city on subsequent urban history in Europe and the Islamic world, investigating both urban fabric and urban ideals. The ongoing ‘Centre for Urban Network Evolutions’ project (UrbNet) is a ground-breaking archaeological research initiative exploring the evolution of urbanism and urban networks from the Hellenistic Period to the Middle Ages. The ‘Social Reactors Project’ at the University of Colorado Boulder is investigating the underlying universal mechanism of ancient and modern urbanism through settlement-scaling theory to provide understanding and possibly guidance for current government and policy makers. Finally, the ‘Cities and Settlements in the Ancient World’ project – run by OIKOS, the National Research School in Classical Studies in the Netherlands – is analysing the historical, material and cultural aspects of the development of the ancient city from the emergence of the first urban centres in Mesopotamia to the transformation and decline of the urban phenomenon in Late Antiquity with an emphasis on the Classical, Hellenistic and Roman Mediterranean. Meanwhile, the *Cities* series, published online by the Guardian in the UK (www.theguardian.com/cities), has brought this topic closer to the wider public.

Yet fundamental questions are still widely and vigorously debated: What is an ancient city? When can we say that a nucleated settlement has

become a city? Why does a city sometime prevail over others and why does it eventually decline? These questions have not yet been definitely answered, especially with reference to central Italy and Rome in particular. The long-term trajectory of Rome is quite well known and established from its early supremacy within Latium vetus in pre-historic and early historic times, to being an emerging power in Italy, during the Republican period, and finally its dominance over the empire, in the first few centuries of our era before the final collapse around the end of the 4th century AD. However, the contributory factors and the determinants of this trajectory that took 'a slightly shabby Iron Age village' to become the 'undisputed hegemon of the Mediterranean' are still very much questioned.¹ In the second part of this chapter, I will present the state of the art on urban formation and urban developments (*urbanisation*) in central Italy, while in this section I will discuss features of *urbanism/urbanisation* on a wider level presenting the current debate on the ancient city, also with particular reference to Arjan Zuiderhoek's recently published *The Ancient City*, which summarises and discusses extensively previous approaches.²

Already in the Bronze Age, but more commonly with the advent of the Iron Age, in the Near East, in Europe and in the Americas, many regions had become organised in small independent political units, generally defined as city-states.³ Since the classic work by Fustel de Coulanges, *La Cité Antique*, published in 1864,⁴ the debate on the characteristics and origin of the ancient city has been immense, but Zuiderhoek's scholarly and at the same time lively book helps us navigate this dense and intricate subject.⁵ As observed by this scholar, the ancient *polis* or *civitas*, according to Fustel de Coulanges, found its origin in a primordial, Indo-European notion of private property, based on claims of land control and household possession through the cult of ancestors. According to Zuiderhoek, Fustel de Coulanges aimed to show that ancient cities came into being in a way fundamentally alien to the medieval and early modern European urban experience, to contrast the Jacobin appropriation of classical ideals to justify their revolutionary aims.⁶ Similarly, explains Zuiderhoek, the other famous model of the ancient city proposed by Max Weber,⁷ was elaborated contrasting the 'modern-medieval city economy' to the 'ancient household economy', in order to justify and explain the origin of modern capitalism.⁸ As correctly emphasised by Zuiderhoek, the famous and dominant model of the ancient city, developed by the ancient historian Moses Finley was strongly influenced by Weber.⁹ According to Zuiderhoek, in Finley's model of the ancient economy, his conceptualisation of the ancient city as a consumer city, derived from Weber and developed in a very particular

direction, served as an explanation for the ancient world's relative economic underdevelopment (compared to medieval and early modern Europe). When summarising the ideas of Fustel de Coulanges, Finley and Weber, Zuiderhoek states: 'in stressing the otherness of antiquity, all three were engaged in a much broader discourse concerning the nature and causes of western exceptionalism, that is, the unique development towards capitalism, the Industrial Revolution and modern liberal society in which western European medieval cities were thought to have played a crucial part'.¹⁰

Besides these fundamental and influential models of the ancient city, Zuiderhoek discussed all major models of urbanism developed by past and current scholarship, which can be summarised and integrated with further discussion as follow:

- (1) As suggested by Zuiderhoek,¹¹ the demographic model can be based either on settlement size, according to which a centre would be urban above 10,000 individuals or in the case of ancient cities, 5,000;¹² the density/nucleation principle, according to which 'cities are places where a certain energized crowding of people takes place';¹³ or the demographic composition of the population. With particular reference to this last variable, Zuiderhoek discusses the urban graveyard model, according to which the proximity and bad hygienic conditions of urban crowding caused high mortality rates, especially among infants/children, which needed immigration to compensate for the deceased population in order to allow growth and sustainable development of ancient cities.¹⁴ However, this theory can be contrasted with the model of increased fertility, according to which early cessation of breastfeeding would lead to higher fertility rates which in turn would outweigh high mortality rates, allowing for population survival and reproduction and eventually the demographic growth generally associated with urbanism.¹⁵
- (2) More classically, the socio-economic model, characterises urbanism by specialisation of labour, social stratification and complementarity between the consumer city and the producing countryside, that together make up the market economy.¹⁶
- (3) The model of urban environment and/or urban landscape, based on the appearance of the ancient city, 'with the presence of central squares or plazas, paved streets, defensive walls and gates, public architecture for religious, political or ceremonial/ entertainment purposes and some element of town planning. It is perhaps in this

sphere that the intuitive understanding of a settlement as ‘urban’ (we know it when we see it) is strongest’.¹⁷

- (4) The political model, according to which ‘Greek and Roman cities were political communities, which possessed the institutions required for autonomous collective decision-making’.¹⁸
- (5) The ritual and identity model according to which cities were communities not only for full members of the political body (*civitas*) but for a wider group of people, including women, children, freedmen, resident foreigners and slaves, who were effectively non- or semi-citizens but would find unity and interactions in the comprehensive and inclusive action of the city rituals and festivals.¹⁹ While religion has often been connected to power as a means of coercion and ideological control (*Religio Instrumentum Regni*), from ancient classical authors²⁰ to Niccoló Macchiavelli’s treatise,²¹ Jorg Rüpke is developing a new dynamic way of looking at religion as a means of actively creating power and the changes that led to early states societies.²²

To these models identified by Zuiderhoek, another has now to be added: the ‘house society’ model, originally developed by Claude Lévi-Strauss and since elaborated on by numerous scholars, with reference to Mediterranean Bronze and Iron Age societies²³ and to central Italy,²⁴ in particular. This model emphasises the role of the family as an institution, with related anthropological and social practices such as marriages and hereditary rights, and seems to offer the missing link between egalitarian pre-urban societies and stratified and hierarchical urban developments; the family is also a key factor, in a dialectic manner, for the creation of state institutions. This view, reminiscent of Karl Marx and Friedrich Engels’ perspectives,²⁵ had already been suggested by Renato Peroni²⁶ and Andrea Cardarelli,²⁷ in their elaboration and definition of proto-urban societies, and seems most promising. In my previous work on the urbanisation of Rome and Latium vetus²⁸ and in an article on the Latin people,²⁹ I have discussed most of the above themes presented by Zuiderhoek with reference to the material culture of this specific region. In the second part of this chapter, I am going to summarise and update this discussion and show how this book contributes to the current debate on urbanisation in general and central Italy, in particular.

Zuiderhoek’s book, these discussions and the rich literature of comparative studies on urbanism³⁰ demonstrate that while the debate on what is an ancient city is still very much open and far from being resolved, it is still

possible to identify some common traits and common trajectories, at least with some limited grounds of variability, that characterise settlements and communities across a great variety of historical and/or chronological settings. These works, in particular, suggest that a common feature of settlements is their ability to create connectivity and generate greater division of labour and specialisation, enhanced technological invention and innovation, monumentalised and communal ceremonial building/public spaces, common ideology and/or religious belief, albeit with costs to levels of equality, quality of life and standards of living, as well as impacts on the environment, which cannot be separated from the emergence of confederations and states. However much of the discussion of these themes, within historical and archaeological circles, has been on a discursive or qualitative level, and therefore it is often difficult to harmonise the different models that have been applied to date into a consistent empirical and/or theoretical framework. A new approach to settlements throughout different contexts should now be within our grasp, however, thanks to both the ease with which information can be disseminated and the facilities that recent developments in information technology offer us the means to model, analyse and statistically test data. As suggested by Monica Smith, ‘the capacities for human interaction in concentrated locations are exercised within a limited set of parameters’,³¹ that should be possible to study quantitatively. Zuiderhoek seems to be sceptical about these interdisciplinary and quantitative comparative approaches to urbanism and urbanisation that ‘may eventually be able to arrive at some universal understanding of urbanism’.³² In contrast, I believe that qualitative discussion and comparative quantitative approaches are not alternatives but complementary and it is still possible to keep details about cultural-historical specificity within wider comparative perspectives.

In this sense Zuiderhoek underestimates a whole tradition of studies from the pioneering work by Louis Wirth³³ to the more recent contributions by Michael Batty,³⁴ both discussed and presented in the recent quantitative approach to Central European urbanism by Oliver Nakoinz.³⁵ The quantitative comparative approach presented in those works, such as in the recent Special Research Topic edited by myself, John Hanson, Scott Ortman and Louis Bettencourt (*Where Do Cities Come From and Where Are They Going To?*; www.frontiersin.org/research-topics/7460/where-do-cities-come-from-and-where-are-they-going-to-modelling-past-and-present-agglomerations-to-u), allows us to connect recent developments in archaeological research with those in other disciplines, including economics, anthropology, sociology and social ecology.

This not only enables us to add historical depth to our models of urbanism, but also to connect understanding about cities in the past and present, offering opportunities to predict their evolution and improve policies in the future. While there is a large array of methods and tools to assess and to analyse quantitatively degrees of urbanism and/or urbanisation processes, such as complex systems theory, settlement scaling theory, agent-based modelling, rank-size analysis, gravity models and space-syntax, in this work I choose to analyse Transportation Systems through the Network Science Approach. After summarising most current research and debate on urbanisation in central Italy, I will show in Chapter 2 why I believe this is a very promising field of research that has been relatively neglected in the past few decades and is definitively novel and unexplored for Iron Age central Italy.

1.2 Urbanisation in Central Italy

Thanks to the work of many scholars over the last few decades our knowledge of urbanisation processes in southern Etruria and Latium vetus (Fig. 1.1) from the Final Bronze Age to the Archaic Period is nowadays much more advanced. In this section, I am going to revise the many different dimensions and/or trajectories of social evolution that scholars have studied in relation to the development of cities in Early Iron Age central Italy.³⁶ The absolute chronology of Bronze and Iron Age Italy is still a much debated question, which has changed from traditional approaches based on pottery typology, to modern scientific radiocarbon dates and dendrochronology. For a brief discussion of the state of the art I refer to my previous work.³⁷ Here, an updated table is presented to synthesise the main relative and absolute comparative chronologies in central and southern Italy (Table 1.1).

Settlement Dynamics

When considering settlement dynamics, in particular (Table 1.2), it is well known that between the Final Bronze Age and the beginning of the Early Iron Age southern Etruria and Latium vetus witness a process of centralisation and nucleation from small dispersed villages, during the Bronze Age, into large settlements of the Early Iron Age on the plateaux, that will be later occupied by the cities of the Orientalising and Archaic Periods.³⁸

This process is generally considered more sudden and revolutionary in southern Etruria where mainly during Final Bronze Age 3 (between the second half of the 11th and the first half of the 10th century BC) small,

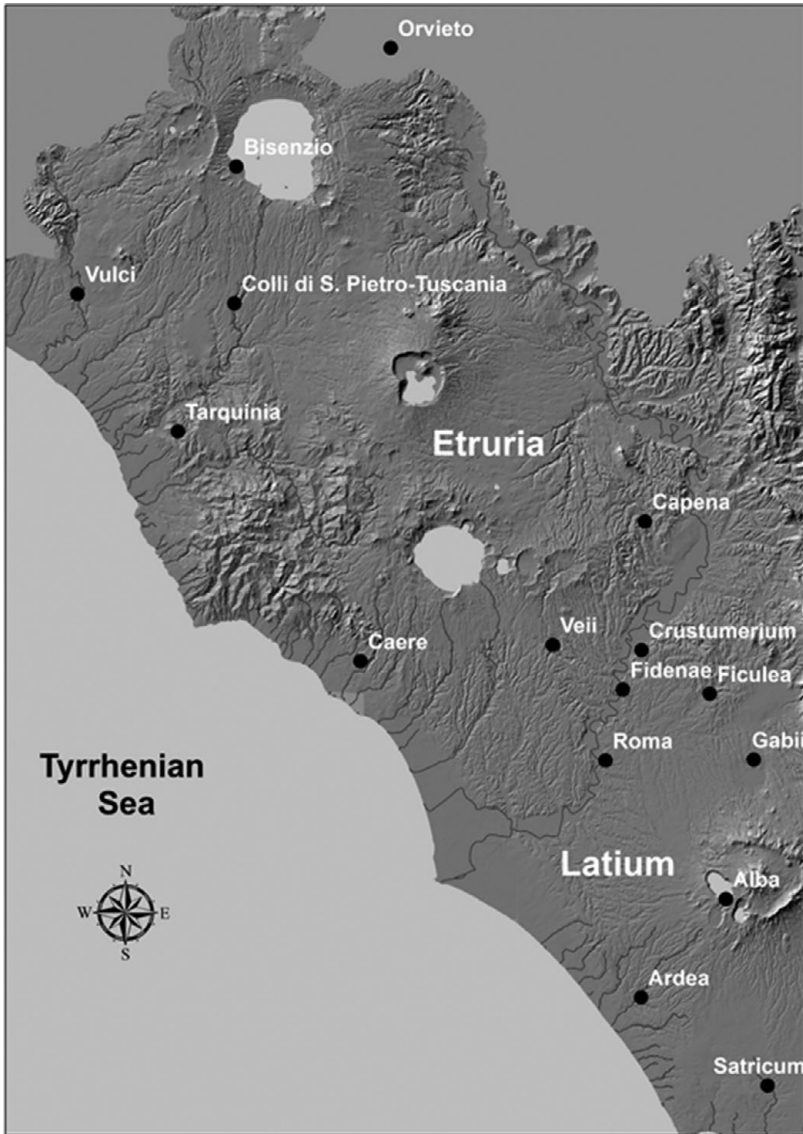


FIGURE 1.1. Southern Etruria and Latium vetus in central Italy.

dispersed villages of the previous Bronze Age (area on average 5–6 ha but sometime up to 20–25 ha) are abandoned. At the same time the wide plateaux (area between about 100 and 200 ha) of the future historical cities (Veii, Tarquinia, Caere, Vulci, Bisenzio and Orvieto) are settled

TABLE 1.1. *Comparative relative and absolute chronologies in central and southern Italy*

						Trad chronology (Colonna, 1976; Ampolo, <i>et al.</i> , 1980)	Dendro- chronology (Peroni, 1994; Bettelli, 1997)	C14 Chronology (Bietti Sestieri, <i>et al.</i> , 1999- 2000)	New absolute chronology 1 (Pacciarelli, 2001, 2005; Nijlboer, 2005)	New absolute chronology 2 (Van der Plicht, <i>et al.</i> , 2009)	New absolute chronology 3 (Nizzo 2007)
Pontecagnano	Pithekoussai	Veio	Tarquinia	Latium							
Proto-Appennine		Grotta Nuova	Grotta Nuova	Grotta Nuova /		1600	1700		1700	1700	
Apennine		Apennine	Apennine	Apennine		1400	1500		1400	1400	
Subapennine		Subapennine	Subapennine	Subapennine		1300	1365/1350		1325/1300	1325/1300	
Protovillanovan		Protovillanovan	Protovillanovan	Protovillanovan		1150	1200		1175/1150	1200	
						1100	1150				
Protovillanovan		Protovillanovan	Protovillanovan	I		1000	1085		1050/1025	1050	
IA		IA	IA	IIA		900	1020		950/925	950	
IB		IB-IC	IB	IIIB		850	950		900 ca.	900 ca.	
IIA	First settlement	IIA-IIIB	II	IIIA		770	880		850/825	825/800	
IIIB	Late Geometric 1	IIC	II	IIIB		750	810				750
Early Orientalising Age	Late Geometric 12	IIIA	IIIA	IVA1		730/720	750		750	725	725
Middle Orientalising Age	Middle Proto- Corinthian 1- Middle-Proto- Corinthian 2	IIIB	IIIB	IVA2		670/660					680/675

Table 1.1. (*cont.*)

						Trad chronology (Colonna, 1976; Ampolo, <i>et al.</i> , 1980)		Dendro- chronology (Peroni, 1994; Bettelli, 1997)	C14 Chronology (Bietti Sestieri, <i>et al.</i> , 1999- 2000)	New absolute chronology 1 (Pacciarelli, 2001, 2005; Nijboer, 2005)	New absolute chronology 2 (Van der Plicht, <i>et al.</i> , 2009)	New absolute chronology 3 (Nizzo 2007)
Pontecagnano	Pithekoussai	Veio	Tarquinia	Latium								
Recent Orientalising Age	Late Proto- Corinthian- Ancient Corinthian	IV	IV	IVB		640/630	Recent Orientalising Phase			630/620	630/620	650/630
Archaic Period	Middle Corinthian	Archaic Period	Archaic Period	Archaic Period		580	Archaic			580	580	580
Early Republican Period	Early Republican Period	Early Republican Period	Early Republican Period	Early Republican Period		509	Early Republican					
Middle Republican Period	Middle Republican Period	Middle Republican Period	Middle Republican Period	Middle Republican Period		400	Middle Republican					
Late Republican Period	Late Republican Period	Late Republican Period	Late Republican Period	Late Republican Period		200	Late Republican					
						31/27						

TABLE 1.2. *Settlement patterns in southern Etruria and Latium vetus from the Final Bronze Age to the Archaic Period*

Pre-urban/ Proto-urban	Proto-urban		Proto-urban/ urban	Urban	
Final Bronze Age 3 (Latial Period I)	Early Iron Age 1 Early (Latial Period IIA)	Early Iron Age 1 Late (Latial Period IIB)	Early Iron Age 2 (Latial Period IIIA-IIIIB)	Early and Middle Orientalising Age (Latial Period IVA)	Recent Orientalising Age (Latial Period IVB) & Archaic Period
1050/1025–950/925	950/925–900	900–850/825	850/825–750/725	750/725–640/630	640/630–509
Nucleation and centralisation of settlements	Large proto-urban centres		Definition of limits or emerging urban centres and internal organisation	Urban realization	Urban monumentalisation
		Foundation of secondary centres	Widespread colonisation of the countryside		
Settlement hierarchy 1/2 tiers	Settlement hierarchy 1/2 or 2/3 tiers	Settlement hierarchy 2/3 or 3/4 tiers	Settlement hierarchy 3/4 or 4/5 tiers		

extensively, with a patchwork occupation of hut compounds interspersed with gardens and allotments. Scholars have calculated that about 15–20 villages are abandoned for each large developing proto-urban centre.³⁹ In Latium vetus the process is more gradual and slightly delayed. In this region, the formation of large proto-urban centres occurs mainly during Latial periods IIA and IIB (between the second half of the 10th and the first half of the 9th century BC) with the occupation of large plateaux often linked to small *Acropoleis* previously occupied during the Bronze Age.⁴⁰ Recent studies, however, have emphasised that in both regions there were more varied and different specific cases and exceptions to the general trends than previously thought, and therefore the two regions are probably more similar than previously assumed.⁴¹

Later during an advanced stage of the Early Iron Age (Early Iron Age 1 Late, around the first half of the 9th century BC) both in southern Etruria and Latium vetus satellites secondary centres are founded by proto-urban centres creating a settlement hierarchy of two to three tiers with primary settlements generally larger than 100 ha in Etruria and generally larger than 40–50 ha in Latium vetus but sometime also between 25 and 50 ha, and small secondary settlements always smaller than 15–20 ha.⁴² Following this, during the Early Iron Age 2, (second half of the 9th and first half of 8th century BC), it is possible to observe a progressively more precise definition of the limits and internal organisation of large proto-urban centres now developing towards urbanisation and consisting of a series of changes markedly visible around the mid 8th century BC. This is shown by:

- (1) Demographic growth of the emerging urban centres, testified by an increased density of sites on the surveyed plateaux.⁴³
- (2) Sharp definition of the boundaries of the inhabited area of the settlements with a concentration of the sites rigorously within the limits of the plateaux and the abandonment of the sites previously located along the external slopes of the plateau.⁴⁴
- (3) Formalisation of these boundaries with the realisation of symbolic⁴⁵ or more functional fortifications.⁴⁶
- (4) The internal organisation of these centres with the creation of public spaces and official building for assemblies and communal activities, cult places and special larger residencies, probably occupied by royal families or aristocratic elites.⁴⁷

At this time, around the mid 8th century BC, there is also a more dense and diffuse occupation of the territory by 'urban' elites⁴⁸ with small aristocratic settlements dispersed around the countryside. This leads the

settlement hierarchy to three to four level tiers with primary settlements (various orders, generally larger than 100 ha but sometime between 25 and 100 ha), secondary settlements (always smaller than 15–20 ha) and small high-status settlements in the countryside generally indicated by small burial grounds.⁴⁹ At this stage, by the mid/late 8th century BC, the proto-urban centres can be said to be properly urban although they will reach a mature consolidated urban stage in a fully monumentalised form only in the Orientalising and Archaic Periods (7th–6th century BC).⁵⁰

Social Hierarchy and Community Identity

When considering the development of social hierarchies and the construction of community identity as mirrored in the funerary evidence (Table 1.3) it is generally agreed by most scholars that princely burials of the late 8th century BC and beginning of the 7th century BC have an important precedent in warrior burials and rich female burials of the full 8th century BC, and they represent only the final point of a long process of social differentiation whose early stages have to be placed at least in the Final Bronze Age.⁵¹ In fact, important discoveries and studies by Anna De Santis and Anna Maria Bietti Sestieri have identified religious and political leaders in a few exceptional male burials of Latial Period I found in the territory of Rome (e.g. Quadrato di Torre Spaccata and Santa Palomba). These burials in fact have a full suit of armour including double shields (identified with the *Salii* shields by Giovanni Colonna), greaves, spears and swords, numerous pottery items, and cult and prestige objects, including a knife, an incense burner, possibly a *holmos* (vase stand) and a cart, which according to Bietti Sestieri and De Santis refer to the political (sword and weapons) and the religious role (knife and incense burner).⁵²

Similarly, it is now generally agreed that the slight funerary variability of Latial Period IIA and IIB and of earlier Villanovan cemeteries (second half of 10th to first half of 9th century BC) is not due to lack or absence of social stratification but to the egalitarian ideology of the newly formed proto-urban communities which tend to mask or hide internal inequalities.⁵³ Further evidence comes again from a discovery by Anna De Santis who excavated and published tomb 6 from Tenuta Cancelliera at Santa Palomba, dated to Latial Period IIB (first half of 9th century BC) and equipped with amazing objects such as a complete suit of armour (including double shields, greaves, spears and swords), an axe, working tools, a cart, small human figures and a gold nail.⁵⁴ In an analogous way, the populist and egalitarian ideology of the city fully formed under the

TABLE 1.3. Social differentiation as reflected in burial customs in Southern Etruria and Latium vetus from the Final Bronze Age to the Archaic Period

Pre-urban/ Proto-urban	Proto-urban		Proto-urban/ urban	Urban	
	Early Iron Age 1 Early (Latial Period IIA)	Early Iron Age 1 Late (Latial Period IIB)		Early and Middle Orientalising Age (Latial Period IVA)	Recent Orientalising Age (Latial Period IVB) & Archaic Period
Final Bronze Age 3 (Latial Period I)	950/925–900	900–850/825	850/825–750/72	750/725–640/630	640/630–509
EMERGING BURIALS	SHARED SYMBOLS OF POWER		WARRIORS AND RICH FEMALE BURIALS	PRINCELY BURIALS	REDUCTION AND DISAPPEARANCE OF GRAVE GOODS
Political and religious leaders (complete suit of armour, knife, cart, incense-burner, holmos (stand?)	Prestige and power symbols (weapons for male burials, spinning and weaving tools for female burials, hut-urn, statuettes, knife) distributed among various individuals		Warrior graves with complete suit of armour and prestige goods (flabellum, incense-burner, metal vases, etc.)	Princely burials with hundreds of pottery vases, precious material vases and ornaments (gold, silver, amber, ivory), drinking-sets, oriental power symbols (<i>flabellum</i> or fan, footrest and sceptre)	Drastic reduction until complete absence of grave goods; family chamber tombs.
Rich infant burial (Le Caprine tomb 5, Latium vetus) with spinning and weaving instruments and knife	Exceptional tomb 6 Tenuta Cancelliera (Santa Palomba): offensive and defensive weapons, cart, statuettes, working tools, knife, gold, many vases		Rich female burials with many ornaments, bronze cist, spinning and weaving tools		

tyrannical regime of the Tarquins imposed a drastic reduction in the number of grave goods until eventually they disappeared fully from Latin burials during the Recent Orientalising Age and the Archaic Period (end of 7th–6th century BC).⁵⁵

Linked to the development of social stratification and urban and state institutions is the problem of the birth of the ‘gens’, identified as a specific institution of the Roman Republican state, but often linked to ‘clan’, ‘lineage’ and ‘family’ organisations that can be clearly identified in the archaeological record, such as in the ‘gentilician central group’ at the Iron Age cemetery of Osteria dell’Osa,⁵⁶ or the aristocratic ‘family group *tumuli*’ of the Orientalising period, related to secondary and local settlements at the periphery of the territory of Rome.⁵⁷ Christopher Smith has offered a detailed discussion of the origin of the ‘gens’, by debating and comparing both literary sources and available archaeological evidence, and rather cautiously suggested that it is very difficult to link the Roman institution, as known from literary sources and classical archaeological evidence, to its predecessors, indicated by Iron Age and Orientalising material culture.⁵⁸

While combining literary narratives and prehistorical material evidence is always risky and must be done carefully, it is the merit of Nicola Terrenato to have laid the foundations for a constructive debate, open also to the inclusion of the growing archaeological evidence. Such evidence has emphasised the key role of the ‘family’ and the ‘gens’ (especially but not only ‘aristocratic’ ones), as active agents and a connecting link in the delicate and still somehow ‘obscure’ passage between pre-urban village communities and urban societies, and later on thorough the whole development of Roman expansion and dominance.⁵⁹

Craft Specialisation

Albert Nijboer⁶⁰ and Johann Rasmus Brandt⁶¹ have studied craft specialisation in central Italy by applying different theoretical models but have both formulated similar craft specialisation processes in the region from the 9th to the 4th centuries. According to these scholars, during the 9th to the beginning of the 8th centuries, pottery was still produced within the household for domestic use only. By the end of the eighth and during the seventh centuries, the formation of the first fortified settlements, the adoption of polyculture (with the introduction of olives and wine), the beginning of social stratification (documented by the appearance of lavish burials), pre-monetary early market exchange and demographic pressure created new socio-economic conditions favourable to the development of

household pottery production, mainly for their own use and some small trading/exchange.⁶² By the end of the 7th and during the 6th century, a population increase, agricultural intensification and technological improvements (such as greater diffusion of the potter's wheels and proper kilns) led to the beginnings of a workshop industry, and eventually large industrial workshops, such as those attested at Populonia, Marzabotto (Etruria) and Acqua Acetosa Laurentina (Latium vetus).⁶³ According to Brandt⁶⁴ and Nijboer,⁶⁵ pottery craft specialisation was paralleled by a similar development in house building, which evolved from simple, small huts to big, complex houses with stone foundations, during the second half of the 7th century.

In addition, Nijboer emphasises that metallurgy production underwent a similar process of increased specialisation. During the Late Bronze Age and the beginning of the Early Iron Age, metalworking was a part-time activity of resident smiths, which operated within a regional or inter-regional network for the exchange of locally exploited raw material. But during the 8th century, significant changes occurred in metalworking: bronze *fibulae* started to be produced in series, and copper alloys tools and weapons were replaced by iron objects.⁶⁶ By the end of the eighth and during the seventh centuries, an increase in the number of iron tools (spearheads, swords, knives, spits, horse bits, components of chariot wheels) is attested in Latin burials, especially in association with luxury grave goods, and in votive deposits at Satricum. This means, according to Nijboer,⁶⁷ that metals were manufactured locally.

Brandt and Nijboer correctly relate craft specialisation to socio-economic changes which occurred in central Italy during the late Early Iron Age, Orientalising Period and Archaic Age. It is important, however, to note some remarkable technological and typological innovations towards specialisation and standardisation, which occurred in Latium vetus already during the late Early Iron Age. Colonna, Carafa and Bietti Sestieri all demonstrate that remarkable innovations such as standardisation of products,⁶⁸ and the introduction of updraft kilns (suggested by the production of red impasto alongside brown impasto vessels)⁶⁹ and possibly of fast potters' wheels (suggested by the presence in Rome of *depurata* vessels presumably of local production⁷⁰) were already occurring in Latial Period III, at least during the 8th century. Similarly, according to Cristiano Iaia,⁷¹ during the 8th century, it is possible to note a greater standardisation in the production of bronze sheet cups and possibly postulate an emerging market exchange-circulation for these objects, rather than simply a more traditional gift-exchange circulation.

Textile Production

Besides traditional studies on pottery and metal crafts, valuable studies by Margarita Gleba and more recently Sanna Lipkin have contributed to uncovering the importance for the Italic economy of a rather hidden and perishable commodity such as textile. Due to the constant association of textile tools (spindle whorls, spools, loom weights) with female individuals in Etruscan and Italic burial contexts, textile production has been generally associated with female gendered activity.⁷² Research by Gleba⁷³ has recently highlighted how the production of ceremonial textiles was an important economic activity, which required highly specialised skills and was generally reserved for women of relatively high status. During the Early Iron Age, this production was mainly confined within the household, as indicated by the regular small quantities of tools generally found within settlements.

Consumption, however, was not limited to family use especially for non-essential, fine, colourful and decorated textiles which were a valuable commodity and often were deposited in high status burials, for example, in Tomb 2 at Santa Palomba Tenuta Cancelleria, *ca.* 11th to 10th centuries,⁷⁴ or later in Tomb 89 from Verrucchio, end of 8th/beginning of 7th century; Isis Tomb from Vulci (Etruria), 7th century; or Barberini and Bernardini Tombs from Palestrina, second quarter of the 7th century;⁷⁵ or dedicated in sanctuaries possibly as part of rituals involving the whole community.⁷⁶ In addition, a progressive standardisation in the shape and weight of the tools indicated that there was a certain degree of specialisation and 'professionalism' practised by individuals within the domestic sphere.⁷⁷ With the Orientalising Age a new mode of production in workshops seems to appear, as indicated by the large number of tools found in specific areas or structures, such as at Poggio Civitate (Murlo) and Acquarossa.⁷⁸

Staple Economy

As far as staple economy is concerned, early cultivation of cereals and legumes has been demonstrated in Latium vetus by research conducted in the Pontine Plain: in this region agricultural activities occurred at least from the Neolithic Period onwards. However, the first introduction of polyculture (cereals, olive, wine) in the region is far more uncertain.⁷⁹ There are some hints that polyculture in the form of production of olives with cereals had begun in central Italy and Latium vetus by the middle of

the 8th century, but the evidence is not conclusive. Land evaluation research, conducted in the Pontine Plain by Ester van Joolen,⁸⁰ demonstrated a slight improvement in the suitability of land for polyculture from the Bronze Age to the Early Iron Age. Unfortunately, pollen diagrams did not show any sign of these kinds of land use in that area.

Taking into consideration the whole of central Italy, however, there are archaeological indicators of an early introduction of polyculture. Grape pips and olive stones, for example, have been found in several 9th and 8th century settlement contexts (Gran Carro, near Lake Bolsena, and Cures Sabini, near Rieti),⁸¹ and vases containing liquids and drinking pots are common in funerary contexts of the 9th and 8th centuries. In addition, a small image of a plough on a bronze incense burner from the necropolis of Olmo Bello in Bisenzio, dated to the 8th century, might be an indication of the existence of iron ploughs at this time,⁸² but the evidence is too scanty to be definitive.

An interesting attempt to link crop processing with state formation processes in Latium (Rome) was undertaken by Laura Motta.⁸³ Her study detected a general increase in the quantity of grain processed during the 7th and 6th centuries, but the situation was not homogeneous. According to Motta, the heterogeneity among the samples signifies the co-existence of different circuits of crop processing in the same community. It is likely that traditional, pre-existing, kin-based production systems survived and co-existed with a new state-based economy. Therefore, Motta suggests that a heterarchical model would be more appropriate to explain Rome's proto-urban complexity than the hierarchical, Marxist theories of production.

A comprehensive study of the faunal economy in central Italy has been recently undertaken by Claudia Minniti.⁸⁴ According to her work, during the Bronze Age settlements show generally a 'self-sufficient primary economy,' based on agriculture and limited husbandry (sheep, goat, pig) for meat supply destined for local consumption; moreover, livestock could have been moved over great distances for pasturage. Cattle at this time were primarily used for traction in fields. But an exception to this practice is the late Bronze Age settlement on the Capitoline hill, where animals were slaughtered and by-products processed. During the final Bronze Age, the first changes are attested in primary economic activities: some sites show the slaughtering of a discrete percentage of steers for meat; it is only, however, during the Early Iron Age that sheep and goat secondary products start to be more fully exploited.

In addition, the site of Rome during the later Iron Age shows a dramatic increase in the consumption of pigs. These animals, which require

minimal effort to keep, rear and feed, might have been considered a valuable option as a consequence of demographic growth (perhaps rendered possible by the intensification of agriculture), which in turn might be an indicator of urban development.⁸⁵ On the other hand, more sophisticated social and economic practices of Latin communities during the late Iron Age seem to be confirmed by the presence at Fidenae of rare and exotic animals, such as the domesticated cat.

Religion and Cult Activity

In several publications over the past forty years, Guidi has demonstrated an interesting connection between the formation of proto-urban centres and important developments in the ritual activities of Early Iron Age Latium vetus.⁸⁶ While in the middle and late Bronze Age cult places were respectively represented by natural caves and open-air bronze objects deposits (in springs, lakes, rivers or pits), during the Early Iron Age some special huts within the settlement area seem to acquire the role of cult places for the whole civic community. Many hut structures of the 8th–7th centuries have been found under the Archaic temples of Velitrae (S. Stimate), Satricum and Ardea (Colle della Noce).

In addition, votive deposits are known from the Quirinal Hill (S. Maria della Vittoria),⁸⁷ the Palatine Hill⁸⁸ and the Capitoline Hill in Rome,⁸⁹ and the cult hut of Vesta has likely been identified in the very heart of the city.⁹⁰ Other votive deposits in Latium are attested in Campoverde and Tivoli (Acquoria).⁹¹ According to Guidi,⁹² the existence of central cult places which served the whole community in the 8th century BC is a sign of incipient urbanisation.

By contrast, Christopher Smith⁹³ connects urbanisation with the stone temples of the 7th to 6th centuries and distinguishes them from ritual activity in open-air deposits of earlier times. Even though Smith admits the existence of social status and ritual activities conducted by the head of the clan group (*gens*) acting for the community already in the 9th century, he tends to interpret votive deposits of the 7th century as an expression of a more ‘individual’ and ‘private’ kind of religion and to downgrade the importance of the huts which preceded stone temples. Therefore, the debate is still open.

Ethnic Identity

A well-known traditional work by the eminent Etruscologist, Massimo Pallottino,⁹⁴ observed a striking coincidence between Early Iron Age

regional material cultures of central Italy (which emerged and differentiated themselves from the middle and late Bronze Age cultural homogeneity) with the distribution of later inscriptions and territories of the historical people as they are recorded in ancient literary sources. Since then several studies, among which probably the most comprehensive is the work by Guy Bradley⁹⁵ on Umbrian ethnicity, have warned against this 'common sense' approach and have adopted a problematised approach to ethnicity. As observed by Bradley, in fact, the traditional equation between material culture and ethnicity can no longer be simplistically accepted, and boundaries among different material cultures in central Italy are often blurred and overlapping, as in the case of Veii and Rome, or Umbrians and Etruscans along the Tiber valley. In addition, he has correctly emphasised that the reliability of literary accounts of such ancient times (Final Bronze Age and Early Iron Age) are highly questionable and that most examples of ethnic group self-designations come from the second half of the first millennium and hardly pre-date 600 BC.⁹⁶

As noted by Bradley himself, some other Italian scholars, such as Renato Peroni,⁹⁷ have adopted a problematic approach to ethnicity. Similarly, Carmine Ampolo has suggested the idea of ethnic fluidity of a central Italian inter-regional cultural commonality (*koiné*).⁹⁸ More recently, Guidi and other authors⁹⁹ have emphasised the fluidity of cultural boundaries based on material culture, while Gabriele Cifani¹⁰⁰ has studied the complex dynamics between ethnic groups along the Tiber frontier by analysing changing settlement patterns in central Italy from the Bronze to the Archaic Age. Finally, Francesco di Gennaro¹⁰¹ has emphasised similarities between Crustumerium (Latin) and Veii (Etruscan), which faced one another from opposite sides of the Tiber River. To conclude, while the original hypothesis by Pallottino can no longer be accepted without being problematised and taken cautiously, the strong relationship between ethnic formation and socio-economic developments (increased social complexity, state formation, urbanisation) in central Italy suggested by this scholar remains valid.¹⁰²

These trajectories identified in different dimension of social evolution in of middle Tyrrhenian Italy between the Final Bronze Age and the Archaic Period also shed new light on the longstanding debate over the origin of the city in central Italy during the Early Iron Age. This debate over the last forty years can be viewed as polarised between two opposite schools of thought, 'Exogenous' and 'Endogenous' (although many scholars actually fall in between). Exogenous (mainly historians, classicists and Etruscologists) highlights the role of external influences (diffusionist model), namely from

the Near East via Greek and Phoenician colonists, in the birth and development of cities and urban aristocracies.¹⁰³ On the other hand, Endogenous (mainly pre-historians and a minority of Etruscologists and classical archaeologists), emphasise autochthonous impulses and local developments towards higher complexity, which can be detected in settlement patterns and in social developments (mirrored by the funerary evidence) already by the end of the Final Bronze Age and the beginning of the Early Iron Age (end of the 11th and beginning of the 10th century BC), if not earlier.¹⁰⁴

The trajectories delineated above, seem to lend further vitality to and provide evidence for the Endogenous over the Exogenous school of thought. The formation of large nucleated and centralised proto-urban centres in southern Etruria and Latium vetus between the Final Bronze and the beginning of the Early Iron Age, and then the colonisation of the countryside first with second- and then with third-tier high-status settlements, points to early hierarchical organisation of the settlements. The evidence of the presence of political leaders both in southern Etruria and more clearly in Latium vetus, by the end of the Final Bronze Age (Latial Period I, second half of the 11th and first half of the 10th century BC), hints at an early presence of social differentiation. Craft specialisation, specialised textile production and differentiation of cultures and preferred domestic animals is well documented for the 8th–7th century BC but hinted also for the later stage of the Early Iron Age in various places of central Italy. The presence of common cult places and spaces suggest the presence of conscious political communities in central Italy at least since the middle of the 8th century BC, while the differentiated yet intermingled material cultures suggest an advanced process of ethnic differentiation in Early Iron Age central Italy, but with mobile communities very open to accept and integrate foreigners and outsiders. Therefore, as will be discussed in Chapter 2, a new paradigm-shift in the conceptualisation of modes of contacts and interactions in the Mediterranean during pre- and proto-history has introduced a new model which makes it possible to overcome the old debate between Endogenous and Exogenous factors in favour of a new perspective of reciprocal catalysing interactions.¹⁰⁵

1.3 Conclusions

Several new international projects investigating cities and cities networks from their origin to Late Antiquity, as well as some recent Cambridge University Press books, such as Zuiderhoek's *The Ancient City* or my own

The Urbanisation of Rome and Latium vetus from the Bronze Age to the Archaic Era, shows that the debate over ancient cities is far from being exhausted, and what defines a city still eludes our classification and characterisation, both from a qualitative and quantitative point of view. However, the Social Reactors Colorado Project, which seeks to understand underlying mechanisms of urbanisation in the past and present to help current and future policies in developed Western societies as well as developing countries, has shown that this debate is very much relevant for us today and attempts in this sense are still worthwhile, both for the advancement of scholarship and the benefit of our communities. As it will be discussed in more detail in Chapter 2, by taking a network perspective, as already advanced briefly in my previous work on the urbanisation of Rome and Latium vetus, this book aims to contribute to this debate, hoping to add a slightly different and novel perspective that will open new lines of research and will have practical applications also in disciplines beyond history and archaeology, such as urbanism and or transportation studies. In addition, by taking a comparative perspective on Latium vetus and southern Etruria, it will try to provide an answer to the question that has puzzled historians a great deal: Why Rome and not Veii? How did a small and not exceptional village, like many others in central Italy, supersede all equal powers and gain supremacy in the region and eventually all central Italy and later all the known world?

CHAPTER 2

Transportation Infrastructures

A New Approach to Interactions

2.1 The Network Approach: Metaphor or Tool?

The Network as a Metaphor

If we take archaeology's current interest in human networks in a broad sense as an interest in understanding human interactions, this is not exactly new to archaeology.¹ This is evident in archaeology's interest in intercultural contacts as an explanation for cultural and socio-political changes, which is also a core theme in changing approaches to Mediterranean urbanisation.² Processual archaeology still approached such changes by taking an over-formalistic approach to it, if it considered interaction at all.

World system theory was probably the first model which introduced a viable framework for explaining the role of intercultural contacts in shaping cultural changes. World system theory, developed by Immanuel Wallerstein to explain the origin of modern capitalism, was applied to Bronze and Iron Age Europe by Andrew and Susan Sherratt in the 1990s.³ According to them, during the Bronze Age, goods, people and ideas came from the Near East to Central Mediterranean to Continental Europe, but continental Europe was not a passive periphery but an active margin. For example, Sherratt emphasised how in the Late Bronze Age, many types of metal Italian and European objects are found in Greece and on the coasts of the Near East.⁴ However, for the Iron Age, Sherratt still maintained the old diffusionist approach, according to which the movements of goods and ideas is clearly from the Near East to Central Mediterranean and then to continental Europe, with a more passive role for central and continental Europe than in the previous Bronze Age⁵ (Fig. 2.1). Another early effort applied Wallerstein's concept of centre and periphery to social and economic interactions in the Near East, Mediterranean and Europe from the 3rd to 1st millennium BC.⁶ Although the editors recognized the Eurocentric bias inherent in World-Systems

Theory, they concluded that “this is something from which we are unlikely to escape” (preface). Nevertheless, the work of scholars who adopted World-System Theory produced some insights into the power dynamics of cores and peripheries and of resistance as a form of interaction.

Another important application of the concept of interaction in archaeology has been the model of peer-polity interactions developed by Renfrew and Cherry (1986) (Fig. 2.2). They suggested that political change which leads to the formation of complex societies generally occurs on a regional level within a network of equal ranked competing polities.⁷ As well summarised and explained by Renfrew and Bahn, peer-polity interaction takes many forms, some of which have been distinguished:

- (1) Competition can be well exemplified by the practice of the Olympic Games.
- (2) Competitive emulation in conspicuous consumption can be illustrated by the construction of magnificent Greek and/or Latin and Etruscan city temples.
- (3) Warfare, as suggested by Renfrew and Bahn, is ‘an obvious form of competition’.
- (4) Transmission of innovation within a sphere of interaction implies that a technical advance made in one area will soon spread to other areas.
- (5) Symbolic entrainment suggests that within a given interaction sphere, there is a tendency for the symbolic systems in use to converge. For instance, the religious iconography in different centres tends to be similar and/or homogeneous.
- (6) Ceremonial exchange of valuables is generally attested among the elites of an interaction sphere, such as in the transfer of marriage partners and/or valuable gifts.
- (7) The flow of basic commodities should not be underestimated. This specifically connects to world system theory. However, the colonial perspective of this theory needs to be mitigated and/or eradicated within peer-polity interactions.
- (8) Language and ethnicity: finally, Renfrew and Bahn remind us: ‘the most effective mode of interaction is a common language’.⁸

Already by the end of the 1990s, scholars such as Gil Stein were questioning the validity of world system theory for the understanding of the role of inter-regional interaction in the development of complex polities and suggested alternative models such as the ‘distance-parity’ or the ‘trade-diasporas’ models. In particular, she applied these alternative models to the Mesopotamian expansion in the Uruk period and demonstrated that ‘the world’s earliest colonial network is best understood through the distance-parity model and

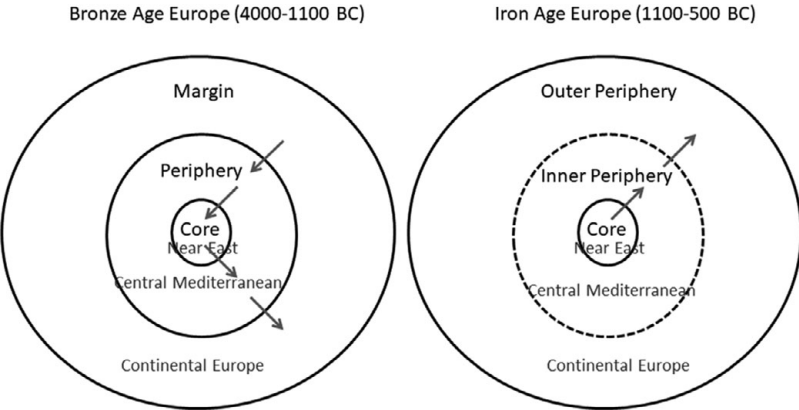


FIGURE 2.1. World system theory applied to Bronze and Iron Age Europe according to Andrew and Susan Sherratt (drawn by the author).

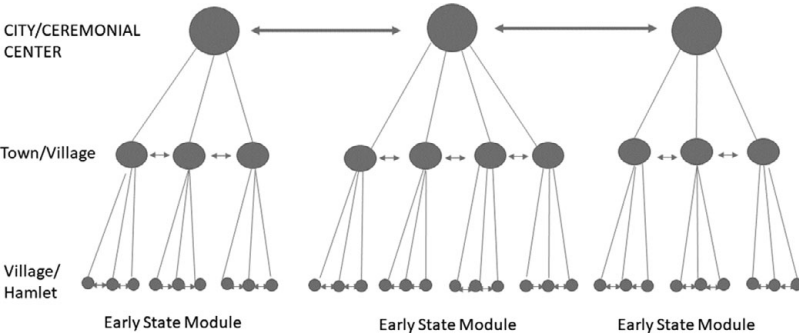


FIGURE 2.2. Trade at the Early State Module level (peer polity interaction). (Redrawn by the author from Renfrew and Bahn 2004, 388).

flexible view of trade-diasporas, where local agency plays a crucial role in structuring power relation between polities'.⁹ Interestingly in that work, she declared: 'I have deliberately used the more flexible term "network" in preference to the more structured, deterministic idea of a "system"'.¹⁰ In this way Gill Stein was one of the first to emphasise the importance of imbalanced power relations between core and periphery and allow for a much more nuanced spectrum of variability in power relation among polities.

However, it has been only in the last few decades that these new themes and views on inter-cultural contacts have been fully developed, thanks also to the new perspectives introduced by recent post-colonial theories. These emphasise the reciprocal catalysing interactions among cultures and reject the old core-periphery perspective of the world system theory. Concepts such

as entanglements,¹¹ hybridisation,¹² Mediterraneanisation,¹³ globalisation¹⁴ and networks¹⁵ remind us that, while degree of intensity and frequency cannot be compared with modern times, the ancient world was much more connected and subject to reciprocal influences than previously thought.¹⁶ Interestingly, a recent study by Peter Grimes has acutely and cleverly synthesised in a dense paper and argument how world system theory and complex system theory can be combined to explain both natural and social evolution in a continuous and homogeneous theoretical paradigm.¹⁷

The Network as a Tool

In the previous section, I have shown how the network perspective and the use of network as a metaphor for interaction are not new to archaeology. Interestingly, as I will show in this section, the application of formal Network Analysis is also not a completely new tool for the field of archaeology. Several pioneering applications of network analysis already appeared in the 1970s and 1980s within the broad domain of the New Archaeology. These were mainly, but not limited to, geographical applications of networks in regional and inter-regional studies. However, both due to the theoretical difficulties inherent to the application of network analysis to archaeological data and the absence of user-friendly software, these applications were followed by only very few studies in the subsequent decades. Only in more recent years archaeologists seem to have begun to appreciate the advantages of social network analysis, and formal network applications to historical and archaeological data are becoming more popular.¹⁸

The approach of network science is based on the central role of structural relations. According to this perspective, the behaviour of a system is not only based on the characteristics of its component (for example in the case of individuals, their age, sex, mentality or belief etc.) but is determined by the nature of connections existing between its parts.¹⁹ In abstract terms, the network is a digraph (representation in form of a diagram) of a system. It consists of *nodes* or *vertices*, which represent the entities of the system, and *edges* or *arcs* which link the nodes and represent the types of connection between the nodes.²⁰ The edges can have a specific direction from one node to another (in which case are represented by arrows or arcs) or can be undirected or bidirectional in the case of reciprocal relations (and in this case are represented by simple lines); relations can also have a degree of intensity (*valued edges* or *arcs*) or not (*unvalued edges* or *arcs*). The nodes or vertices can be individuals and their relationships might represent sentiments, such as friendship or hatred, or family links. Nodes or vertices can also be microscopic entities, such as neurons linked by neuronal

connections, or macroscopic entities, such as communities, cities, states and nations, linked by political alliances or trade relations. The network science approach allows us to analyse the systems with their internal relations and study them qualitatively and quantitatively with a systemic approach.

The last two or three decades have seen an exponential growth in the interest in the network approach both within scientific and humanistic disciplines and also in the public domain. A number of volumes have popularised principles of network science such as the ‘Small World’, originally elaborated by the psychologist Stanley Milgrom, according to which two strangers can always be linked through a small chain of acquaintances.²¹ At the same time, as noticed by Knoke and Yang, there has been a proliferation of works based on the network approach to study natural phenomena and complex social systems within the mathematical and physical disciplines.²² Consequently, the network approach has become a real interdisciplinary paradigm, used in a wide range of disciplines: from sociology to ethnology to economy, to geography, biology and medicine including historic and humanities disciplines.²³

Within the archaeological disciplines, as early as the 1970s and 1980s it is possible to identify the first pioneering applications of network science, mainly constituted by the study of fluvial or terrestrial geographical networks for predicting the birth of central places, such as Roman London²⁴ or 12th and 13th century Moscow;²⁵ other studies suggested the network approach to be a useful tool in the study of regional survey data²⁶ or in the study of prehistoric trade exchanges.²⁷ After this first series of studies followed by a few decades of interesting but discontinuous contributions and applications,²⁸ there has been a new explosion of studies in the last twenty years.²⁹ Several recent collections of papers³⁰ and monographs³¹ testify to the vitality of the network approach in archaeology with case studies from a great variety of geographical and chronological contexts.³²

In the next section I will discuss the importance and contribution of the network approach, both as a metaphor and as a tool, to the study of urbanism in the Mediterranean during the first millennium BC and central Italy, in particular. While in the final part of the chapter I will discuss the potential of studying communication and transportation networks for understanding the social and political organisation of the communities that created and maintained them.

2.2 Networks and Urbanism

Network as a Metaphor

As suggested by Knappett,³³ the fascination for intercultural contact and influence ultimately goes back to the historical approach of Gordon

Childe, his broad perspective on cultures across Europe and the Near East and the apparent 'diffusion' of cultural traits from East to West.³⁴ With Childe's fundamental work, *The Dawn of European Civilization* (1925), the so-called diffusionism paradigm emerged, which saw the origin of civilisations radiating from the more 'developed' East to the 'barbarian' West. According to this paradigm, the model of the 'city' originated in the Near East during the fourth to third millennium BC, was transmitted to Greece via the Mycenaean civilisation and developed there until the flourishing of the first city-states in the 8th century BC.³⁵ Only at that stage was it thought to be introduced to the West Mediterranean via Greek and Phoenician colonists.³⁶

This model dominated archaeological scholarship until a few decades ago. Subsequently, several scholars started to see local processes in the western Mediterranean that led to important independent developments prior to the arrival of the first colonists (for example in Spain,³⁷ Sardinia,³⁸ southern Italy³⁹ and, as far as we are concerned, middle Tyrrhenian Italy.⁴⁰ Not only important local developments in the Western Mediterranean were detected but also signs of opposite commercial routes and influences from West to East began to be identified.⁴¹ Thus, a completely new perspective of reciprocal catalysing interactions between East and West started to emerge.⁴²

Crucially, instrumental to this revolution in understandings of Mediterranean contacts during the first millennium BC has been the network concept. As early as the 1990s, partially following up on the peer-polity interaction model introduced by Renfrew and Cherry,⁴³ Wilkins suggested adopting the network paradigm to explain urbanism in middle Tyrrhenian Italy during the Early Iron Age and the Orientalising Period.⁴⁴ However, the network paradigm has only recently really succeeded on a wider Mediterranean scale. Several scholars have in fact emphasised the importance of Mediterranean connectivity in the shaping of European and Near-Eastern developments since hunter-gatherer times through to recent historical periods,⁴⁵ which is, ultimately, in line with the ground-breaking work by Fernand Braudel.⁴⁶ With reference to urbanism, Osborne suggested correctly that what made urbanism appealing to citizens was urbanism elsewhere.⁴⁷ Cities and urban societies did not develop in the Mediterranean as a cascade process but were involved in a long-distance network of trade and contacts across the whole Mediterranean basin that created a fruitful development of reciprocal catalysing interactions.⁴⁸

The concept of the network has been particularly successful in Irad Malkin's explanation of Greek civilisation as a 'decentralised network', that

is, as a series of nodes distributed along the Mediterranean shores and developing together with reciprocal influences. In contrast, the Roman Empire would have been a 'centralised network' with the Romans radiating their influence across the Mediterranean regions.⁴⁹ At this point it is easy to see why the idea of a network of cities competing and exchanging goods, people and ideas was so appealing.⁵⁰ In fact, when considering the beginning of the first cities in the Mediterranean during the first millennium BC more generally, it can be observed that the process of beginning urbanisation took place in most regions within the timeframe of three or four generations, with substantial contemporaneity across the areas.⁵¹

To conclude, the network concept has been instrumental in the development and successful consolidation of a revolutionary new perspective on Mediterranean urbanisation in the first millennium BC over the past few decades, finally replacing the traditional diffusionist model of the introduction of the idea of the city from the more 'developed' Eastern Mediterranean to the 'barbarian' West Mediterranean. A last note, however, ought to be added. We must be aware that ideas and views often radicalise as they enter the historiographical account. For example, Childe himself in the conclusion of his book *The Dawn of European Civilization* affirms:

The development of industry and commerce in Greece and subsequently in Temperate Europe was as much dependent on Oriental capital as the industrialization of India and Japan was on British and American capital in the last century. On the other hand, European societies were never passive recipients of Oriental contributions, but displayed more originality and inventiveness in developing Oriental inventions than had the inventors' more direct heirs in Egypt and Hither Asia. This is most obvious in the Bronze Age of Temperate Europe. In the Near East many metal types persisted unchanged for two thousand years; in Temperate Europe an extraordinarily brisk evolution of tools and weapons and multiplication of types occupied a quarter of that time.⁵²

In this way while he clearly declares that Greece and temperate Europe were 'dependent' on Oriental capital, he also allows for non-fully passive role of Europe, which according to him was an 'active' recipient of a greater culture.

Network as a Tool

When the network is considered as a tool, the applications of network analysis in studies of the development of complex societies are not so common.⁵³ Probably the most influential model is the classic work by

Rihll and Wilson on the formation of Greek city-states.⁵⁴ In their work, Rihll and Wilson developed a model that enabled the prediction of the emergence of Greek city-states through analysing their location and characteristics (importance, size, distance from one another) in relation to the location and characteristics of other settlements in the same interaction system.⁵⁵ This model has been recently revised by Bevan and Wilson and remains a benchmark for similar applications.⁵⁶ Recent developments include work on the gravity model by Wilson Evans, Knappett and Rivers on Aegean Greece,⁵⁷ Filet on Iron Age France⁵⁸ and Bevan and Paliou on Pre-Palatia Crete.⁵⁹

Beside Rihll and Wilson's model, the most common application of network analysis related to the development of complex societies and urban communities can be summarised in two main groups of studies: analysis of elite and cultural networks, mainly but not only through community detection techniques, and the analysis of transportation systems and more specifically terrestrial transportation networks, in which my work on central Italy has been one of the pioneering applications among the scholars of the last generation. Transport networks and the importance of studying them to better understand the polities that created and maintained them will be covered in the next section. In the remaining part of this section, I will review briefly application of cultural networks with a special focus on Italy.

A few years ago, Emma Blake successfully applied social network analysis to Bronze Age commercial networks in the Italian Peninsula. With her analysis she demonstrated that the regional groups emerging during the Early Iron Age in the Italian Peninsula and identified by distinctive and internally homogenous material cultures, possibly corresponding to 'ethnic' and or 'political' entities, could be already identified by commercial connections among Final Bronze Age communities.⁶⁰ This is quite fundamental because it suggests that existing economic ties and social relations might have contributed to the consolidation of ethnic and socio-political groups. Another interesting application of network analysis to cultural phenomena in central Italy, is the study of cultural transmission and local identity evolution in northern Etruria during the late Hellenistic times (350–80 BC) by Raffaella Da Vela. In her work Da Vela discusses and shows the potential of the construction of bi-modal and uni-modal networks and their analysis through different types of clustering and similarity indices to study processes of cultural transmission and/or segregation, belonging or isolation, including intra-site analyses.⁶¹

An application that is growing in popularity in the study of cultural ties for a better understanding of emerging complex societies and urban polities

is the community detection method using Louvain technique. Recently Camilla Mazzuccato has applied archaeological similarity networks to building structures (households used as nodes) at the late Neolithic site of Çatalhöyük in Turkey. She has used Louvain community detection techniques to uncover patterns of social relations and processes of group identity formation and negotiation at the intra-site level. Her work revealed a middle period highly cohesive and robust network, which seems to speak to a dense, tightly knit community where, in parallel with a high density of material connections, all the buildings are equally rich and none has a disproportionate amount of connection. For the Late period network, the role of geographical location seems to be less relevant than in the Middle period network. Additionally, the Late period network is much more fragmented and less robust than the earlier ones and several buildings are disconnected from each other when the network is binarised. Together with a low global density score, the late network accounts for the highest centralisation value. This configuration suggests a much less cohesive settlement in this period, where there is an increase of the central role of some buildings, together with a general contraction of material relations, which might indicate a more dispersed and less egalitarian social arrangement.⁶²

Louvain community detection techniques have recently also been used by Ivan Cangemi to study Etruscan and Latin communities in Early Iron Age central Italy.⁶³ While not focusing on transportation systems, the detection of communities in this work through the analysis of burial evidence has allowed the identification of an important internal route from Lake Bolsena to Rome through the interior of southern Etruria. The importance of this route and the connection between Rome and Bisenzio seems to be confirmed also by the communal use of hut-urns to bury the deceased in the early phases of the Early Iron Age⁶⁴ and by a completely independent work I have been conducting on metallurgical composition of Archaic bronze cult figurines in central Italy, which showed how high temperature furnaces were probably used both in the area of Bolsena during the Iron Age and in the area of Rome in the Archaic period.⁶⁵

The Davis model of community detection has also been used by Lieve Donnelan to explore community dynamics at an emerging indigenous urban site in southern Italy, which showed signs of intense contact both with Etruscan and Greek communities (900–600 BC). By using two-mode model networks between burials and grave goods objects, she calculated different indexes such as network cohesion and centrality measures.

Network cohesion showed expanding and contracting, suggesting probably the existence of tension and a tight control of funerary behaviour from the community. While, the study of centrality of selected nodes suggested that an increase in crop storage has played a significant role in the development of state power and the urbanisation process at Pontecagnano.⁶⁶

While the main application of network analysis to Early Iron Age central Italy in my work has been to transportation and communication geographical networks, during my Marie Curie Fellowship, I also explored the structure and functioning of these communities based on cultural ties.⁶⁷ I constructed bi-modal networks of Etruscan and Latin systems connecting with a link sites and types of objects associated with those sites. Then I converted the bi-modal networks in uni-modal networks based on the association of the same types of objects in two sites. Archaeologists are now aware that the presence of the same objects in two places might indicate the origin and the destination of those objects, but there might be many more intermediary passages that are hidden from the archaeologist's observation. Still it seems to be a safe assumption that some basic connection might exist between two places that share the same type of objects with or without intermediary passages.

After constructing the uni-modal networks I calculated some standard measures, such as: average distance, average degree, network density, degree centralisation and betweenness centralisation. This analysis resulted in similar trends in all measures over time for both the Etruscan and Latin region (Fig. 2.3). This seems to suggest that the Etruscan and Latin system worked in a similar way and were rather comparable in their socio-economic and political structure,⁶⁸ as also suggested by Cangemi's work.⁶⁹ It might be interesting to apply Louvain community detection techniques also to the cultural data and networks I have collated to see if these results are confirmed, modified or somehow complemented.

2.3 Why Transportation Networks

As shown by the monumental work of the Copenhagen Polis Centre Project, some city-state polities were the result of disintegration of macro-states, while some others originated from a common process of urbanisation, on the ground of demographic and/or economic growth, nearly simultaneously and/or in close chronological sequence, in neighbouring and/or otherwise inter-connected regions. In some cases, city-states within a region shared a common language and culture and were organised in a religious and/or political league, but still maintained political and

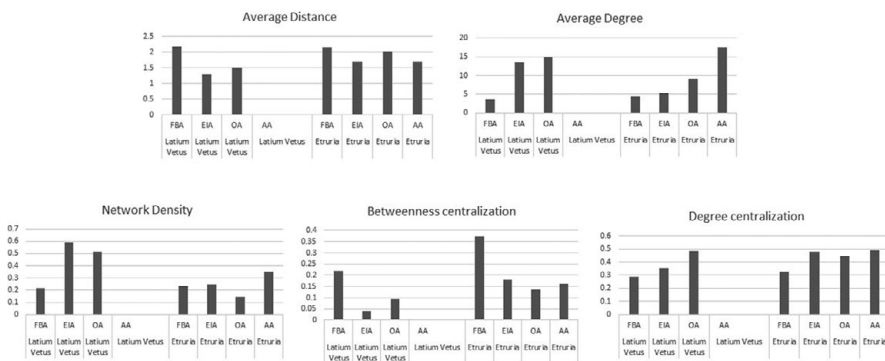


FIGURE 2.3. Characterising measures of southern Etruria and Latium vetus cultural networks from the Final Bronze Age to the Archaic Period: average distance, average degree, network density, degree centralisation and betweenness centralisation.

decisional autonomy. As anticipated above in Section 2.1, often these organisation took the form of the ‘peer-polities’,⁷⁰ but sometimes they could be organised in hierarchical systems, in which some polities were hegemonic and some others dependent. Dependent cities did not have any control on foreign policy and had to pay a monetary and/or troop tribute to regional central governments. Independently from their political organisation, these generally small entities were not autonomous or autarkical from an economic point of view and needed some degree of interaction with other nearby and/or more distant political entities.⁷¹

A huge literature has been devoted to the study of such interactions among different systems of city-states. Analysing the degree of interdependence, hierarchical organisation, integration and/or competition is of pivotal importance to understand why some systems maintained a longer equilibrium and/or some others collapsed in a short time, and/or eventually progressed to form vast empires. In the past most studies focused on neighbouring polities interactions by focusing only on the attributes of the singular polities and using a bi-dimensional space. To exemplify this approach, it is possible to mention various contributions of the New Archaeology⁷² or the tradition of works on rank-size analysis, introduced by the classic work by Johnson,⁷³ followed by Kowalewski and colleagues,⁷⁴ and perfected by Falconer and Savage⁷⁵ and Drennan and Peterson.⁷⁶ The rank-size rule is based on empirical observations and a mathematical explanation of its application has still not been provided. However, recently Enrico Crema has modelled rank-size settlements fluctuation and has offered new insight into its mechanisms and assumptions.⁷⁷ With particular reference to Pre-Roman and Roman civilisations the rank-size rule has

been applied to Etruscan and Latin polities,⁷⁸ Roman Spain,⁷⁹ Egypt⁸⁰ and Asia Minor,⁸¹ the Roman Empire⁸² and specifically to the polity of Rome in a long-term perspective from its origin in *Latium vetus*, through its supremacy in central Italy, to its domination in the whole known world.⁸³

As mentioned in Section 2.1, since the 1960s and 1970s many scholars have worked on models of spatial integration, especially gravity models, resumed and perfected also in recent years.⁸⁴ These studies investigated hierarchical relations in terms of relative predominance of the sites, trying to identify the various factors (such as topography and/or socio-economical features) that determined the importance of one site over another one. However, this approach does not investigate in detail the interaction and/or integration at the political level. How much did polities pursue factionary and peculiar interests or how much were they concerned by the common interest? Did they care for the benefit of the regional system or were they in competition, searching for their own individual survival? In order to answer these questions, it is essential to analyse material evidence that represents these types of political interaction. Rather than other types of material culture, such as pottery, metal objects and/or cultic architecture,⁸⁵ in this work I have chosen transportation and communication infrastructures because they allow for a multi-period quantitative and mathematical comparative approach and because they have been relatively neglected in recent decades especially for the region under study.

Transportation infrastructures can be considered the outcomes of social interactions and interactions between societies and environments. Particularly, terrestrial routes can be considered as the result of the interplay of multiple factors: they are essential for permitting inter-settlement cooperative processes (information exchange, trade and defence) in times before telecommunications and, at the same time, they need some level of cooperation to be established.⁸⁶ As already mentioned in the Introduction, the geographical system of transportation and the social system of interaction are tightly connected by a permanent interplay.⁸⁷

Actor network theory⁸⁸ and assemblage theory⁸⁹ provide the theoretical background for this work, while network science and geographic information systems (GIS) provides the methodology and the tools to build the argument. Traditional spatial analyses used to consider settlement analysis in a flat dimension and allowed us to consider sites just in relation to their attributes and/or their nearest neighbours. Network science allows us to see settlement groupings as a complex system where each settlement is seen in relation to all other settlements in the system. It also provides tools to analyse the properties of the single settlements and the all-settlement system, always

considering the settlements not in isolation but always in relation to one another (see Sections 2.1 and also 3.2, with references cited there).

Assemblage theory and actor network theory, which are specifically philosophical approaches (ontological turn), do not provide a set of tools and methodology such as network science, but they do provide a complementary underpinning by looking at social reality as assemblages (De Landa 2006) and/or macrostructures of nested scales (Latour 2005). More specifically in assemblage theory, actor network theory and network science: (1) the property of the whole emerges from interactions between the constituent parts at each scale and (2) while the simplest entities can be conceived of as assemblages of some sort, conversely, assemblages can be considered entities in their own right.

These theoretical premises of the ontological turn have led some geographers to elaborate a new concept of site that seems particularly useful when thinking about routes and transports connections and their relation to settlements. Marston and other authors suggest seeing a site as an 'emergent property of its interacting human and non-human inhabitants'. In this view, sites as entities do not precede or post-date the connectivity that brings them into reality, either internally (intra-site) or across networks (inter-site), but they are mutually interlinked.⁹⁰

Thinking specifically about settlements and transportation routes in term of assemblages and actor network theory is a quite an interesting and fitting case-study. People are human agents grouped into wider political entities (e.g. villages, cities) that are assemblages and can be considered as nodes/agents in themselves as part of wider assemblages, such as the political and ethnic regions of Etruria and Latium vetus. Paths or routes are things and the relationship between the human agents and these things is their creation and maintenance, which require a certain degree of coordination, integration and/or control among the entities to be realised. In other words, inter-polity interaction among villages and cities (human agents) is somehow mediated also by the creation and maintenance of the paths-routes among them (compare Fig. I.1 in the Introduction). The importance of such systems is self-evident: they influenced the development of past societies enhancing trade dynamics and affecting the prosperity of a civilisation and its complexification.⁹¹ Summarising, terrestrial routes or terrestrial transportation infrastructures both shaped and were shaped by the societies that created them and the environment in which they existed in a clear example of feedback loops.⁹²

However, any archaeologist, geographer or other practitioner who try to use spatial analyses within a network frame will experience that while

providing perfect conceptual backgrounds flat-ontologies and nested scales cannot be so easily and immediately translated into formal analysis and that while (social) reality seems to be free-scale,⁹³ its analysis through the historical lens and its representation through bi-dimensional maps cannot be completely scale-free after all.⁹⁴ In this sense, the further implementation of network approaches (also in combination with GIS applications⁹⁵ and mathematical models such as settlement-scaling theory⁹⁶ are desirable and might help overcome this impasse.

In the past, transportation routes, especially Roman roads with their clear and imposing monumental appearance, have been the focus of traditional topographical research and landscape archaeology both at the centre (e.g. *Forma Italiae* volumes published by the Roman topographic school led by Castagnoli and later Sommella or the *Atlante Tematico di Topografia Antica* (ATTA) and *Latium vetus* volumes edited by Lorenzo and Stefania Quilici Gigli) and at the edges of the Empire.⁹⁷ However, regional or supra-regional studies specifically focused on transportation infrastructures have been less common.⁹⁸ In addition, terrestrial transportation infrastructures have been studied to understand better trade opportunities and relationships in the past and develop interpretations and theories on the origin and development of ancient economies.⁹⁹

On the contrary, the study of transportation infrastructures for understanding the political and social organisation of the communities that created and maintained them has been pioneered only by some scholars for the ancient world. From Chevallier¹⁰⁰ and Taylor¹⁰¹ to Crumley and Marquadt¹⁰² and, more recently, Purcell¹⁰³ and Mattingly¹⁰⁴ for the Roman Empire and the provinces; Laurence¹⁰⁵ for Roman Italy; Nakoinz¹⁰⁶ and Filet¹⁰⁷ for Pre-Roman Europe; while Potter,¹⁰⁸ Boitani,¹⁰⁹ Izzet¹¹⁰ and recently Tuppi¹¹¹, and I¹¹² have focused specifically on central Italy. To these the works by Santley on the Aztec transportation system,¹¹³ Jenkins on the Incas network,¹¹⁴ Smith on ancient states and empires in general¹¹⁵ and Hendrickson on the Khmer Road System (9th to 13th Centuries AD) in mainland Southeast Asia¹¹⁶ can be added. The various contributions in the pioneering volume edited by Trombold in the 1990s, and recently reprinted, on transportation systems in the New World are also worth mentioning.¹¹⁷ In the last few years, Menze and Ur have studied transportation networks systems in northern Mesopotamia in the 3rd millennium BC,¹¹⁸ while Mark Altaweel and colleagues have studied the structure of the territorial system of the Khabur triangle (Syria) from the Middle Bronze Age to the Iron Age.¹¹⁹ Finally, as already mentioned in Section 2.1, the scholar Irad Malkin has adopted a network perspective as a metaphor and

as a heuristic concept and has compared the polycentric maritime network of Greek cities and colonies to the centralised road network of the Roman Empire.¹²⁰ However, apart from a few exceptions (Fulminante, Nakoinz, Menze-Ur, Altaweel and others), most of these studies adopted a qualitative approach that while valuable does not allow formal assessment or wider comparative perspectives. Only recently new studies conducted in regions of Pre-Roman and Roman Europe,¹²¹ and Pre-Roman and Roman Italy,¹²² have shown the potential of novel quantitative studies based on network science approaches and/or GIS applications and have suggested that this is indeed a growing and important field of research.¹²³

To conclude this section, I would like to review my recent work in this direction which has constituted the preparatory work for this book and hopefully will represent the basis for further collaborative research that will follow.¹²⁴ My initial pioneering work applied formal network analysis to early Latin cities. In a first exploratory analysis I applied traditional centrality indexes (betweenness-centrality, degree-centrality and closeness-centrality indexes¹²⁵), while in a subsequent, more refined, application, a single new combined and tailored index was developed in collaboration with Spanish colleagues.¹²⁶ These applications of formal network analysis highlighted some interesting correlations between river networks and Bronze Age primary centres on one hand, and road networks and Early Iron Age primary centres on the other. This means that terrestrial routes were instrumental in the development of Early Iron Age proto-urban Latin centres and Archaic cities, while river connections might have been more important, at least at a local, regional scale, during the earlier Bronze Age.

In more recent work, conducted during my Marie Curie Fellowship at the University Roma Tre with Alessandro Guidi, and developed in collaboration with Spanish colleagues, I started comparing the Latin and the Etruscan System, by exploring their structural qualities and their local and global efficiency.¹²⁷ We also developed some modelling that allowed us to understand the different power dynamics that resulted in quite different types of balance and equilibria or lack thereof in the two regions.¹²⁸ This book builds upon those works and explains why two regions with similar starting points and similar developments – Etruria and Latium vetus – had such a different outcome and why in the end Rome and Latium vetus prevailed over their rival. Were the starting points so similar or was there some difference? How did things work in the two regions and how did they develop through time? By adopting a network science approach this book will compare southern Etruria and Latium vetus to one another, to

highlight similarities or differences that might explain the final outcomes of the two regions. Fluvial and terrestrial networks of the two regions will be studied through their characteristics and their structure to understand the different potentials of the two regions and how they developed their infrastructure which ultimately contributed to their success and/or decline.

2.4 Conclusions

While increasing in popularity, formal applications of network analysis in archaeology are still relatively limited when compared, for example, to the rapid and widespread diffusion of GIS applications. At the same time a polarisation seems to have emerged between those who use the network model only as a metaphor and those who apply social network analysis also as a tool in the investigation of archaeological data. It is probably not yet possible to identify two different schools of thought but somehow one can sense a growing gap between scholars who use networks in these differing ways. In a recent discussion, I argued that both approaches represent valid heuristic tools and scholars who use the idea of network as a metaphor and those who embark in actual formal analysis should both be respectful of other people's work.

As emphasised in his introduction to *Network Analysis in Archaeology*, Karl Knappett argues that in comparison to a distribution map, a detailed formal network analysis of the same data requires a scholar to think more deeply about the nature of the nodes and their attributes and the type of their connections. Is a site primary or secondary? What function does it have? One also must define the links between nodes: their intensity (value), their direction, their frequency.¹²⁹ Similarly thinking about trade and exchange in a network perspective allow us to change old paradigms and see transmission not only in term of diffusion from a centre to a periphery but in term of reciprocal relations and bi-directional exchanges.¹³⁰

As shown in this chapter the network approach has become a powerful tool in urbanism studies both used as a heuristic metaphor and a tool of analysis. The adoption of the network model has allowed us to think about colonisation and urbanism in the Mediterranean during the first millennium BC in a completely new and different way. Malkin proposed a network conceptualisation for Greek colonisation, while Wilkins, Bintliff and I have expanded this concept to Mediterranean urbanism during the first millennium BC in general, in line with current new ideas on the Early Iron Age and Orientalising Period such as Mediterraneanisation, hybridisation, globalisation and connectivity.¹³¹

The application of network as a tool of analysis has shown its potential in the study of emerging complex societies and urban polities, both with reference to cultural networks and geographical networks. More specifically the analysis of cultural networks has proved most successful in the study of cultural transmission, and processes of segregation, belonging and/or isolation, as well as ethnogenesis and the identification of social integration both at the regional and intra-site level.¹³² As my initial work suggested and this book will illustrate more fully the analysis of transportation networks (both fluvial and terrestrial) can be fruitfully applied to better understand the structure and the functioning of ancient polities and more specifically emerging urban polities.

CHAPTER 3

Data and Methodology

3.1 Data

For this work, settlements from Latium vetus and southern Etruria from the end of the Bronze Age to the end of the Archaic Period have been considered. These sites are very well known and documented thanks to a long tradition of studies that goes back to the first topographic studies conducted within the tradition of the aristocratic grand tours of Rome and the Roman countryside during the 18th century. British and German aristocrats, fascinated by the possibility of interacting and getting closer to ancient authors through the contemplation and study, were the first to produce catalogues and descriptions of the monuments and environment of the so-called Campagna Romana, including both the immediate surroundings of Rome and the southern Etruscan region, respectively, to the south and north of the Tiber river.¹ Subsequently this early activity of survey and documentation was continued by the antiquarian tradition of the late 19th to early 20th century² and the more recent landscape and topographic traditions before³ and after World War II, by both Italian⁴ and international scholars.⁵

Finally, in the last few decades of the 20th century many important research projects have been conducted by Italian and/or international teams with modern standards and up-to-date methodologies that have greatly improved the knowledge of the region not only at key excavated sites but also widely in the territory around them. Among these works ought to be mentioned the volumes of the *Forma Italiae* (Roman School of Topography), the volumes of the *Latium vetus* series (by Lorenzo and Stefania Quilici Gigli) and the work of John B. Ward Perkins⁶ and Tim Potter⁷ in southern Etruria. In addition, an important survey of pre- and protohistorical sites in the territory of Rome was led by Anna Maria Bietti

Sestieri,⁸ while various survey-projects and synthesis works have been conducted both in Latium and Etruria, by scholars of the Roman school of prehistory and proto-history, founded by Renato Peroni.⁹ At the same time, the coastal area around the mouth of the Tiber was investigated by the Malafede survey project,¹⁰ while the Pontine Plain and the Nettuno area were intensively surveyed by teams led by the University of Groningen (Peter Attema).¹¹

A project directed by Helen Patterson and Christopher Smith, with the collaboration of Helga di Giuseppe and Rob Witcher, focused on an enhancement project of the original Tiber Valley project of the British School of Rome.¹² The Sabine region, partially included in this work, has also been investigated by the Galantina project.¹³ Finally, the Suburbium project, led by Andrea Caradini and Paolo Carafa, has conducted a systematic survey and documentation of both Rome¹⁴ and its territory; the resulting GIS is available on-line for scholars and the public.¹⁵ This work is now being continued and enhanced by the new Latium vetus project, directed by Paolo Carafa, to produce a similar tool at the regional level in collaboration with Regione Lazio (Fig. 3.1).

At the same time in recent years some synthetic works have been published, which have been points of reference for the present study. Firstly, a project co-ordinated by Regione Lazio has revised all previous studies and produced the *Repertorio dei Siti Preistorici e Protostorici del Lazio*, a very special and useful tool to approach a great quantity of data with a synthetic but also very detailed approach. For Latium vetus, I have used data already collected for *The Urbanisation of Rome and Latium vetus from the Bronze Age to the Archaic Era*,¹⁶ also made comparisons with the important work on the same region by Luca Alessandri.¹⁷ For Etruria the most important synthetic works for the Final Bronze Age are the works by di Gennaro¹⁸ and Barbaro;¹⁹ for the Mid Tiber valley Schiappelli's²⁰ work is very useful; while Iaia and Mandolesi²¹ have produced a synthesis of the later Early Iron Age sites for the whole of Etruria. Finally, for the later Etruscan phases, the work by Marco Rendeli on the territorial organisation of southern Etruria in the Orientalising and Archaic Periods²² has been important. All these works have been up-dated based on the review of *Studi Etruschi* and major Italian and international journals, proceedings of specialist conferences²³ and exhibition catalogues.²⁴

These settlements are primarily known from either excavation or survey, although geophysical prospection has been used in recent years (e.g. by teams led by the British School at Rome and the University of Siena), which provides new data especially on the built environment and the

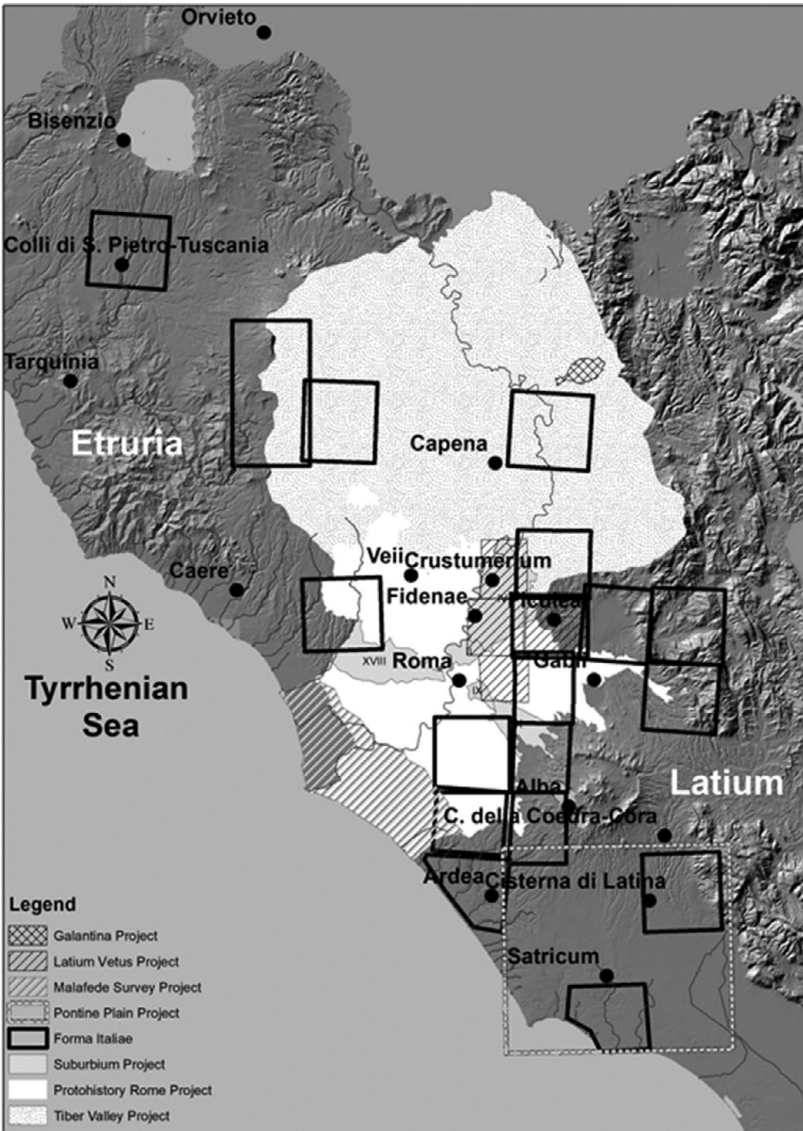


FIGURE 3.1. Survey project conducted in central Italy with modern fieldwork methodologies and recording standards.

organisation of the space within nucleated settlements and opens new perspectives for multi-scalar analyses (compare initial work in this direction in Chapter 6). To build the database of sites with their size/area occupied and geographical location, some assumptions have been made following a

long tradition of study present in central Italy. According to these assumptions, settlements are hypothesised in the case of coherent orographical units even if only few sherds are available from survey and/or excavation. This normally applies mainly to Bronze Age and Early Iron Age sites, for which the evidence is scarcer. In addition, some other sites identified because of literary sources but for which archaeological evidence was not available have also been included. This second assumption mainly applies to the Latin region rather than the Etruscan one, for which literary sources are less abundant.

I have considered the maximum period in which the settlements co-existed without major changes and obtained seven time slices:

- Final Bronze Age 1–2 (FBA 1–2): 1175/1150–1050/1025 BC
- Final Bronze Age 3 (FBA3): 1050/1025–950/925 BC
- Early Iron Age 1 Early (EIA1E): 950/925–900 BC
- Early Iron Age 1 Late (EIA1L): 900–850/825 BC
- Early Iron Age 2 (EIA2): 850/825–730/720 BC
- Orientalising Age (OA): 730/720–580 BC
- Archaic Period (AA): 580–500 BC

Both terrestrial and fluvial communications have been considered in this study. To construct the terrestrial and the fluvial routes networks a bidirectional link has been established between two settlements directly adjacent on a terrestrial or a fluvial route without any settlement in between. The fluvial routes have been based on digital data of modern rivers provided by Regione Lazio and published on the website of Ministero dell'Ambiente (www.pcn.minambiente.it/viewer/). While some studies are available on the changes of the Tiber River route through time,²⁵ to my knowledge there are no studies available at the regional level. To eliminate recent channels and irrigation works and to obtain the network most likely to have been present in antiquity, the modern rivers have been selected with a query performed in GIS about the superimposition of modern rivers on alluvial deposits, because these are the most likely channel that were probably present also in antiquity.

The terrestrial communication and transportation routes have been reconstructed from hypotheses advanced by various scholars. For Latium vetus the reconstruction by Lorenzo and Stefania Quilici Gigli,²⁶ elaborated at the regional level for the Archaic Period, has been used. For the Etruscan region, however, a comprehensive study is still lacking.²⁷ In order to hypothesise the terrestrial links, proposed reconstructions by various authors have therefore been considered: Timothy W. Potter,²⁸ Andrea

Zifferero,²⁹ Patrizia Tartara,³⁰ Paolo Brocato,³¹ Flavio Enei,³² Maria Bonghi Iovino³³ and Andrea Schiappelli.³⁴

The different interpretations have also been tested by considering their alignment with settlements discovered after the publication of these works. According to the topographical principle the existence and/or use of older tracks has been assumed if older settlements coherently align with later archaeologically attested roads (Roman and later) and or with natural morphological routes (e.g. river valleys, ridges etc.) and/or significant archaeological landmarks, such as funerary tumuli and/or bridges, forts. This principle has been traditionally and commonly applied in topographical studies both in Italy³⁵ and in Germany,³⁶ for example, but also in the archaeology of the New World.³⁷

Fig. 3.2 shows a summary of the terrestrial network of path in Iron Age southern Etruria and Latium vetus with indication of the sources of the interpretations.³⁸ ‘Position S’ indicates those paths hypothesised on settlement alignments. Unfortunately, it has not been possible to find enough information on paths and routes in southern Etruria during the Final Bronze Age and therefore this time slice for terrestrial routes in Etruria has been omitted from the analyses. Both settlements and communication routes have been considered constant within each time slice. In this sense, the analysis concerned static networks rather than an evolving system.

However, this does not mean that the system is constant in the five periods. Some sites are abandoned and others are founded: therefore routes are not the only thing that changes but the settlements do too. Finally, to consider the geographic constraint of the territory, the links between settlements have been weighted on the linear distance between each pair of settlements. In collaboration with my Spanish colleagues, this simple but reasonable approach was chosen because the region is spatially limited and relatively homogeneous with scarce orographic variability.³⁹ It ought to be mentioned here that routes and paths have not been reconstructed topographically at a detailed, small scale but only schematically at a large scale for the purpose of building the networks. In future work we are planning to reconstruct paths and routes within a GIS platform that will make available the detailed topographical data for specialists and for the public.

3.2 Methodology

From Exploratory Analyses to Complex Network Modelling

As discussed in Chapter 2, the network approach, used both as a metaphor and as a tool, has been fruitful in advancing research and knowledge, both

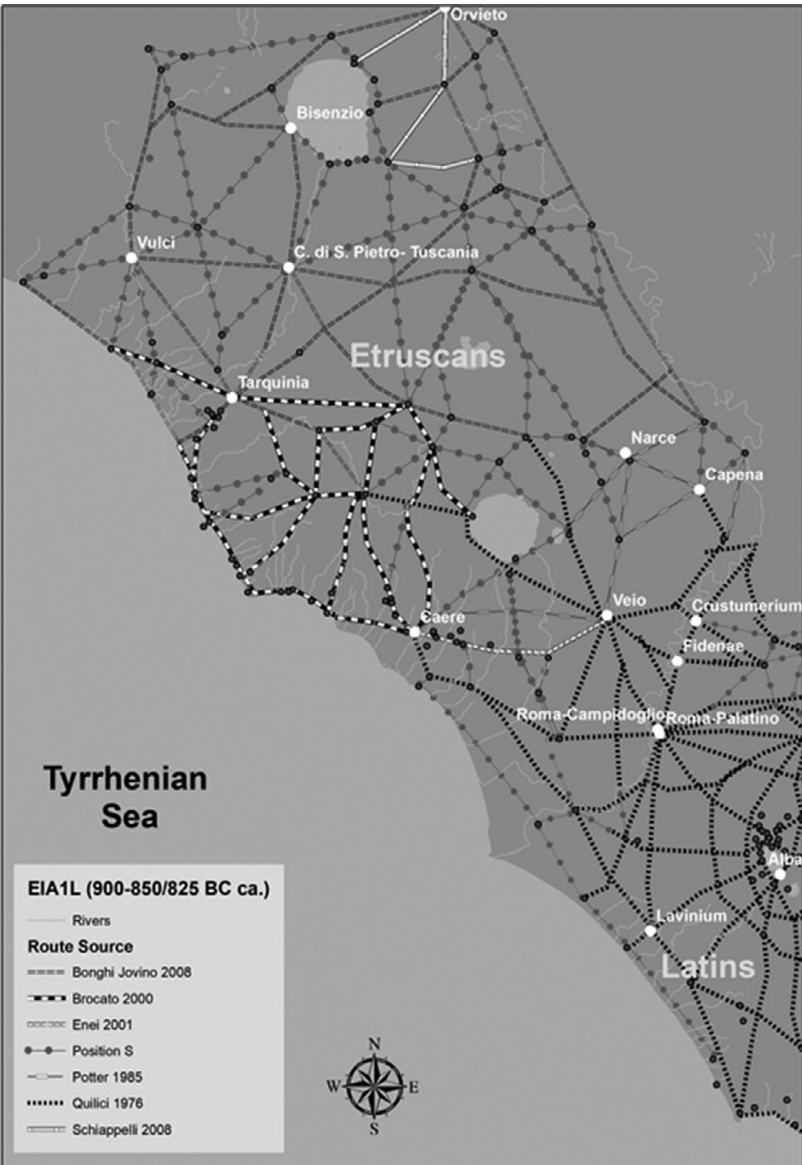


FIGURE 3.2. Reconstruction of Early Iron Age terrestrial routes in southern Etruria and Latium vetus according to various scholars (Position S = routes hypothesised on the basis of settlements' alignments).

within the general realm of archaeology and in the specific field of urbanisation and with reference to pre-Roman and Roman Italy in particular. In this study, I have chosen to use a network science approach because it allows one to study urbanisation in southern Etruria and Latium vetus as global systems not only considering cities as static points in space but also studying their relations and reciprocal integration. By providing visualisation and quantitative analysis, the network approach allows also the two systems to be compared in an objective and less impressionistic way. Different sets of tools from network science have been adopted that will be described in more details in the following chapters together with the discussion of the analyses and the presentation of the results. Here these tools will be introduced and described, and their problems will be discussed at a more general level, and the route that led to their choice illustrated.

The starting point of the research was the application of traditional centrality indexes, such as degree centrality, closeness centrality and betweenness centrality.⁴⁰ These measures are widely used and common in network analysis and had already been successfully applied in the first pioneering applications of network science to archaeology with reference to transportation systems⁴¹ and were also used more recently.⁴² Those indices have been calculated in order to compare the importance of sites predicted by network analysis with the political and/or economic significance of the sites, indicated by their relative ranking based on size, which follows specific settlement patterns observed to be significant in the region, according to many scholars⁴³ and coherent also with the historical information and archaeological evidence available for those sites.⁴⁴ Then the association of these variables has been tested through correlation analysis. This first exploratory analysis showed that the association was significant but not validated statistically with a high degree of confidence. Therefore, a more robust statistical method has been developed in collaboration with some Spanish colleagues to further test the observed association. We created a combined index, which provided much better results and a statistically more significant association.⁴⁵ This new index also showed that the better results were achieved when a weight based on linear distance had been introduced. Therefore, in subsequent analyses this weight has always been considered. Finally, an ego-network approach has been applied and the centrality indexes of all major sites larger than 80 ha have been compared to one another in order to have a better picture of the potentiality and structural characteristic of the system, not only at the global but also at the local level.

The second, more sophisticated step, of the research was the comparison of the efficiency of the two systems, in order to assess if there was some environmental and/or geographical advantage for one of the two players, the

Etruscans or the Latins. For this purpose, both widely used network science efficiency measures, and less common ones have been adopted. More specifically average strength (or average weighted degree), local and global efficiency indexes, as well as smallest positive value of the eigenvalue of the weighted Laplacian matrix or algebraic connectivity (L_w) have been calculated for both fluvial and terrestrial transportation systems in Etruria and Latium vetus in order to compare the different mean of transport between them, within the same region, and between the two different regions. Those measures and indexes will be described in more detail in Chapter 5, but here I would like to emphasise how all these measures have been weighted on the linear distance because, as mentioned above, this proved to be significant and provide more statistically valid results. This specific aspect of the methodology will be further discussed in the second part of this section, when considering in more detail the significance and implication of some of the assumptions and choices made in this work for further work and research.

Finally, to properly understand how the two systems worked and understand their internal power dynamics some modelling has been performed. Each applied model corresponds to a different hypothesis about the dominant mechanism underlying the creation of new connections. After locating the nodes at the positions inferred from the archaeological record, we started adding links according to a specific criterion. Once we had generated several synthetic versions of the networks, we compared them to the corresponding empirical system in order to determine which model fitted the data better and therefore was more likely to resemble the actual forces at work. To evaluate which synthetic networks were closer to the empirical networks we used five characterising measures, some of which were also used in the previous step of the research: the average strength, the average edge length, the clustering coefficient, the global efficiency and the local efficiency. In order to validate the three proposed models, we tested whether the synthetic networks that they generated were able of reproducing the structural features of the empirical networks. However, evaluating the performance of the models by merely looking at the properties one by one is not accurate-enough. Therefore, to assess the overall agreement between the properties of empirical and synthetic networks (i.e. by considering all four of them at once), we defined also a difference function that will be described in more detail in Chapter 6.⁴⁶

Discussion of Some Assumptions and Choices Made in the Present Work

As already explained, both the analysis of the efficiency of the system and the modelling have been based on weighted measures, based on the simple

linear distances between the settlements. Adopting the geodesic distance as the estimate for link cost is likely the most significant approximation that was reasonably adopted given the relative homogeneity and contained dimensions of the regions under study: modern Lazio, which comprises both southern Etruria, to the north of the Tiber, and Latium (both *vetus* and *adjectum*) to the south spans for no more than 17,200 km² (Touring Club Guide). This simplification allowed the development of well-defined models that allowed a better understanding of the mechanisms of power underlying the creation and maintenance of the Etruscan and Latin terrestrial communication systems.

To improve the present work and application and allow a wider applicability of the model, it would be interesting to integrate these analyses and models within a GIS platform. For example, it could be interesting to compare the results of the current analyses with those calculated on a complete matrix of all least-cost paths between every pair of nodes. The integration within a GIS environment would also allow us to consider another aspect, that we have disregarded in our abstract framework but is a constitutive element of real maps, namely the presence or absence of intersections at crossroads. Fig. 3.3 shows how differently the cost of walking is calculated if it is approximated to a geodesic distance (a), as in our abstract model, or if it is calculated in a GIS environment (b), in which case each stretch is counted twice (so-called Steiner Tree Problem). While I have not repeated all the analyses of this work on least-cost-path applications on the region under study, in Chapter 6, I present some results from least-cost-path analysis which aimed specifically at comparing pre-Roman routes with later Roman roads.

However, it must be said that least-cost-path analysis does not always allow for crossroads either. In addition, this methodology is undergoing severe scrutiny because its application is very much dependant on the position of the settlements and therefore an incomplete and/or missing dataset might affect greatly the output of the analysis.⁴⁷ In collaboration with some German colleagues, we are currently developing and adapting for Italian data, a new methodology developed for Early Iron Age southwest Germany, that allow the limitations of least-cost-path analysis to be overcome. The approach, developed by Oliver Nakoinz and Franziska Faupel, uses path-associated features in a combination with a density approach to reconstruct pre-Roman paths, which are not monumental in nature and less easy to date and identify. This approach is basically a formalisation and an optimisation of the traditional approach of using alignments of burial mounds as indicator for pathways.⁴⁸ This novel method⁴⁹ is based on the

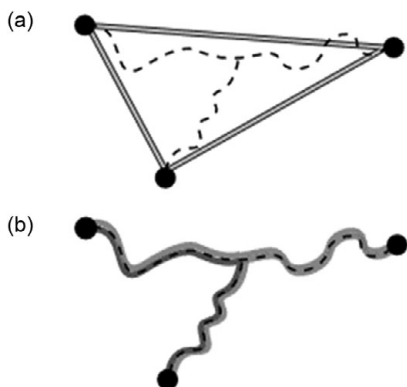


FIGURE 3.3. Example of three hypothetical settlements connected by paths that share stretches (so-called Steiner Tree Problem). In (a), the cost of each connection is approximated by the geodesic distance; in (b), they are estimated through the walk between them. In this way, each stretch is counted twice. (From Prignano et al. 2019, fig. 2)

same assumption but uses the density of sites to extract linear structures as density ridges. Graph-based pattern recognition approaches can be used to fill the gaps in this model. Though, sometimes it is argued, that linear structures mainly indicate borders, there is no contradiction to pathways. The result can be verified by additional information, such as forts, bridges or other elements of transport infrastructure corresponding with the lines. In contrast to network-based pattern recognition approaches (e. g. relative neighbourhood graphs), this approach has the advantage of not requiring the pathway to cross the monuments exactly, which would be rather unrealistic. This approach allows for main pathways which cross clouds of points and do not zig-zag between points. In contrast to traditional approaches, this is fully reproducible⁵⁰ and hence much better suited for research. To adapt the methodology to the Italian case study, not only burial mounds but also general burial grounds, secondary settlements and or sanctuaries will be used as indicators for pathways (burial mounds in fact are not so common, for example, in the Latin region). We will then use road-cutting features⁵¹ as elements of transport infrastructure to verify the lines and alignments. It will be interesting to compare the results of this work, which will be published in another paper, with the reconstruction based on traditional topographical reconstruction applied in this work. However, even the first experimental application seems to provide promising results. Fig. 3.4 shows the routes in Latium and Etruria reconstructed using the model developed by Franziska Paupel for southwest Germany

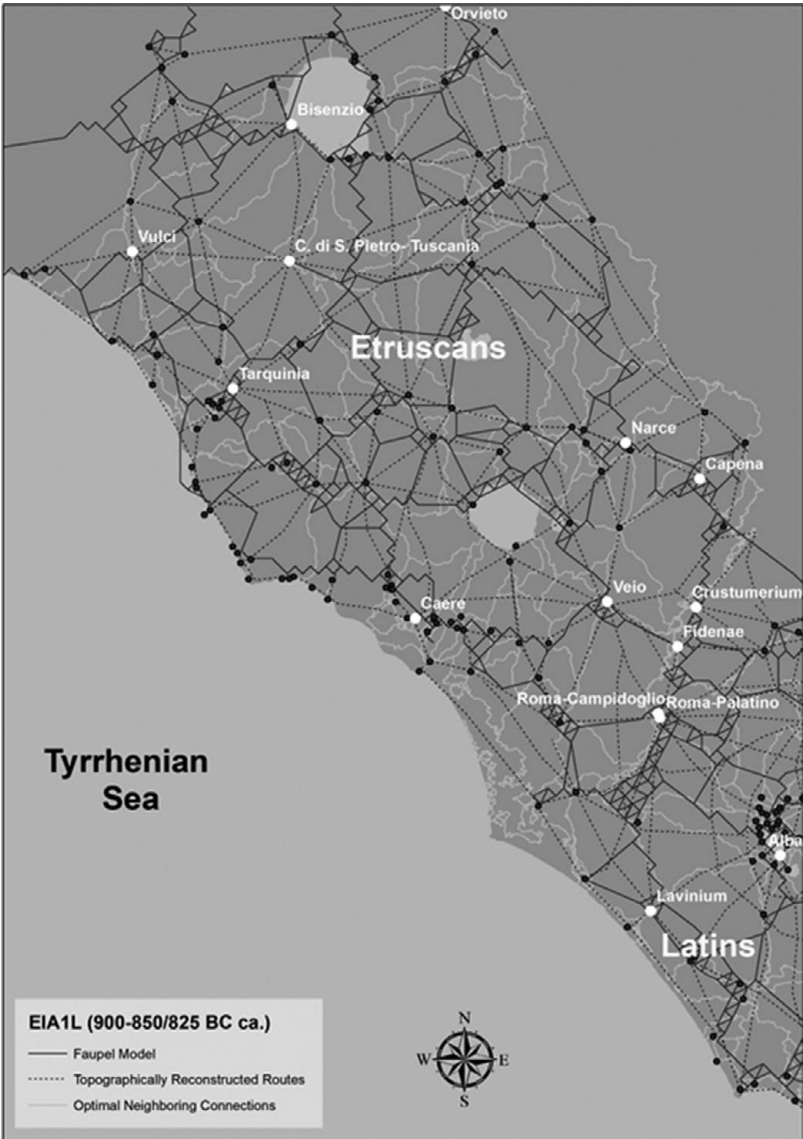


FIGURE 3.4 Comparison between different method of reconstructing terrestrial routes in Etruria and Latium vetus: the model developed by Nakoinz and Faupel for pre-Roman paths in southwest Germany; topographically reconstructed routes; and least-cost optimal neighbour network connections.

compared with terrestrial routes reconstructed topographically and with the least-cost path optimal neighbour network connections. Even a simple visualisation shows a great degree of overlap between the three methods. In further work we will assess analytically the similarities and differences between these different reconstructed networks.

3.3 Conclusions

In this chapter, I presented the data used in the current work. These data are the results of a long tradition of studies that goes back to the 19th century and that in the last decades has produced some excellent fieldwork research and synthesis work, without which the analyses conducted in the present work would have been impossible.

I have also explained how the fluvial and terrestrial transportation networks have been built and which tools and methodologies have been used to analyse them. I also discussed some assumptions and initial choices that have been made in the present work and that I am currently developing and progressing in further collaborative continuations of this research.

In this work, networks have been analysed as abstract model, and the cost of travelling has been approximated to the geodesic distance between two sites. In future work we are planning to develop an integrated GIS platform in which cost of travel will be more precisely calculated. However, this development requires resources and collaborations that are being developed and that go beyond the limit of the original project.

CHAPTER 4

Network Analysis Centrality Indexes

4.1 Methodology

The starting point of the research was the application of traditional centrality measures (betweenness centrality, closeness centrality and degree centrality) to terrestrial and fluvial settlement networks systems in Latium vetus and southern Etruria from the Final Bronze Age to the Archaic Period to compare the behaviour and characteristics of the two regions and start detecting similarities and differences.

Firstly, Latin, and Etruscan settlements have been classified as *central places* or secondary centres according to their size, because historical and archaeological knowledge of the region has already established a correlation between size and importance of the settlement and therefore size can be reasonably used as a proxy of socio-political and economic centrality. For the Bronze Age, settlement larger than 6 ha have been considered central places while for subsequent ages settlement larger than 15–20 ha have been considered primary. These thresholds have been established on settlements size distribution frequency diagrams (Fig. 4.1), and on similar thresholds established by Barbara Barbaro and Francesco di Gennaro for Etruria in the Bronze Age¹ and by Marco Pacciarelli and Alessandro Guidi for Etruria and Latium vetus in the Early Iron Age.²

Secondly traditional network centrality measures such as betweenness centrality, closeness centrality and degree centrality have been calculated for terrestrial and fluvial networks of Latin and Etruscan settlements from the Final Bronze Age to the Archaic Period. At this point the percentages of sites predicted to be ‘central’ by both their size and their centrality measures have been calculated. In a previous application of this exploratory analysis, settlements were ranked according to their size and all N settlements larger than 5–6 ha in the Bronze Age and 18–20 ha in the Early Iron Age were identified

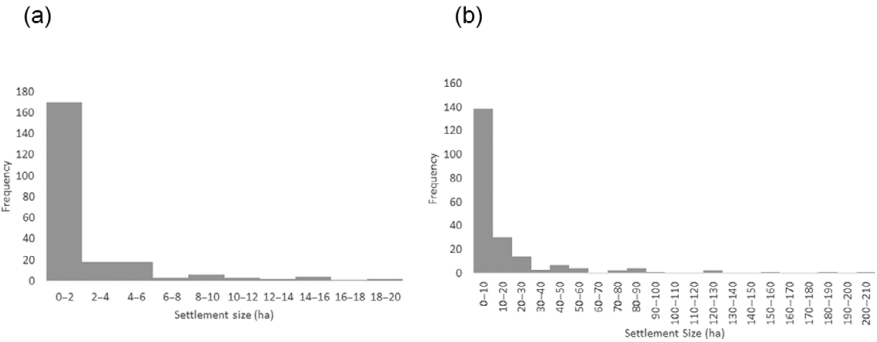


FIGURE 4.1. Examples of size frequency diagrams. (a) Final Bronze Age 1–2; (b) Early Iron Age 2.

	vertexID	settlement	size	area	Predicted central Sites by size	Normalized Degree Centrality	Predicted Central Sites by degree	Predicted Central Sites both by size and degree (%)
	1	Roma	1	2100000	1	0.132075472	1	
	2	Gabii	1	918782	1	0.113207547	1	
	3	Ardea	1	848969	1	0.075471698	1	
	4	Alba	1	756100	1	0.028301887		
	5	Ficulea	2	552909	1	0.08490566	1	
	6	C. della Coedra-Cora	2	542885	1	0.056603774	1	
	7	Crustumerium	2	519072	1	0.037735849		
	8	Satricum	2	507408	1	0.075471698	1	
	9	Astura	3	464995	1	0.028301887		
	10	Cisterna di Latina	3	448530	1	0.066037736	1	
	11	Fidenae	3	413473	1	0.056603774	1	
	107	Gallicano	3	397783	1	0.047169811		
	12	Valmontone-Tolerium	3	394611	1	0.075471698	1	
	13	Corcolle	3	335871	1	0.028301887		
	14	Lavinium	3	334476	1	0.08490566	1	
	15	Bovillae	3	298673	1	0.056603774	1	
	16	Velletri	3	287060	1	0.056603774	1	
	17	Tivoli	3	280909	1	0.056603774	1	
	18	Lunghezza-Collatia	3	279314	1	0.066037736	1	
	19	Ficana - M. Cugno	3	254142	1	0.037735849		
	20	Palestrina	3	242783	1	0.056603774	1	
	21	T. Torrino-Politorium?	3	229770	1	0.037735849		
	22	Tellenae	3	213244	1	0.08490566	1	
	23	S. Giovanni in C.	3	208097	1	0.037735849		
	24	Nomentum	3	186019	1	0.047169811		
	25	M. Giove-Corioli	3	181672	1	0.075471698	1	
Totals					26		17	66

FIGURE 4.2. Centres predicted to be central by their size and by their normalised degree centrality, calculated as percentages on the total number of sites of that phase (Latium vetus, EIA2: terrestrial routes).

and highlighted in an Excel sheet for each phase (see Fig. 4.2). The same settlements were ordered according to their centrality index from the highest to the lowest and the same number (*N*) of settlements was highlighted.³ In the current revision of that analysis, the thresholds of centrality for the different degrees were established from the observation of values of the

degrees in relation to the central places indicated by size. (For the different thresholds for the different periods and for different indices, see calculations in Appendix C). Then the settlements predicted to be 'central' both by their size and their centrality measure were calculated as a percentage of the number of settlements predicted to be 'central' only by their size.

In this way it was possible to calculate the percentages of centres predicted to be central places both by each index and by the size in the two regions from the Final Bronze Age to the Archaic Period. Finally, the statistical correlation between the settlements' centrality measures and their sizes (as already said, a proxy of their importance and socio-political and economic central role) was calculated. In this way, by comparing fluvial and terrestrial networks over a long period of time, it has been possible to understand which means of transport was more important in which period and for which region and which means of transport had a greater influence in the development of proto-urban centres.

Admittedly, this methodology implies the comparison of two variables that have been partially determined and influenced by each other. Therefore, in this revised application we decided also to apply a more robust predicting method which is the prediction or confusion matrix. In this way it has been possible to verify which centres predicted to be central by their size were also predicted to be central by their degree centrality. The prediction or confusion matrix tests predictions and correlations in complex matrices with the use of a logic table that cross-tabulates predicted and observed examples in four options: false–false; false–true; true–false; true–true. This method will be illustrated in more detail in Appendix C, with the calculation of some more detailed measures used to analyse the matrix. In this way, it has been possible to compare theoretical predicted results (assuming that all centres predicted to be central by size would be central also for the centrality indices) with the real occurrence of the centrality indices and evaluate their inter-correlation. As will be shown below, results from the two approaches are not dissimilar.

In addition, centrality indexes calculated for each single site have also been considered. All settlements larger than 80 ha during the Early Iron Age both in southern Etruria and Latium vetus were included: their centrality measures were calculated for the different periods and were compared in a chart. In southern Etruria, Veii, Tarquinia, Cerveteri, Vulci, Orvieto and Bisenzio were included. In Latium vetus only Rome and Gabii were selected. In this way, it has been possible to consider and compare the characteristics and the connectivity potential of the major Etruscan and Latin proto-urban centres over a long-term perspective. The

network centrality measures used in this preliminary analysis are described from a mathematical point of view in Appendix C and illustrated briefly below.

Betweenness centrality indicates the degree to which an actor controls or mediates the 'relations between other pairs or dyads of actors that are not directly connected. Actor betweenness centrality measures the extent to which other actors lie on the geodesic path (or the shortest distance), between pairs of actors in the network'.⁴ At this point it ought to be noted that distance in a network is not a geographical distance but the number of links which connects two nodes. In other words, the betweenness centrality measures the extent to which a node or actor lies on the shortest route connecting each pair of other nodes/actors in the network.⁵ Wasserman and Faust suggest normalising the actor betweenness centrality by dividing it by the maximum theoretical value of $\frac{(g-1)(g-2)}{2}$ assuming each pair has only one geodesic. 'The standardised actor betweenness centrality is 0.0 when the original betweenness centrality is 0 and it is 1.0 when node i falls on the geodesic path of every dyad of the remaining $g - 1$ nodes. Therefore, the closer the standardised betweenness centrality is to 1.0 the more the actor controls or mediates relations in the network.'⁶ (For detailed mathematical explanations see Appendix C.)

The closeness centrality of an actor/node, developed by Sabidussi,⁷ measures the extent to which a node/actor is close to all other actors/nodes in the network. It is based on the total distance between the node/actor and all other nodes/actors, where larger distances imply lower closeness centrality values. Closeness and distance refer to how quickly an actor/node can interact with others, for example by communicating directly or via few intermediaries. As already observed for the betweenness centrality, the geodesic or the shortest path is a key concept and by distance is meant the number of links which connect two nodes and not the geographical distance. Similarly, closeness centrality might vary with network size. Therefore, Beauchamp suggested that the index of actor closeness centrality should be standardised by multiplying it by the maximum number of nodes in the network minus 1.⁸ (For formulae and their explanations see Appendix C).

The degree centrality measures 'the extent to which a node connects to all other nodes in a social network' and indicates how easily information can reach a node. It rests on the assumption, that the more links and neighbours a node has, the higher the probability that node will receive information. Actor degree centrality, however, may vary with the size of the

network (g or the number of nodes/actors). In fact, the larger the network, or the number of its nodes/actors, the higher the potential of each single node/actor is to be directly linked to other nodes/actors. For example, an absolute degree centrality of 3 (which means direct links to three other actors), might represent a high value in a network of five nodes/actors but would be a low value in a network of fifty or more nodes/actors. Therefore, Wasserman and Faust suggest that to eliminate the effect of variation in degree centrality caused by the size of the network, it should be normalised: the normalised degree centrality of a node is given by its degree centrality divided by the maximum number of possible connections with other nodes/actors which is the total number of nodes minus one, the node itself. In this way, it is possible to yield the 'proportion of the network members with direct ties to actor i . Proportion varies between 0.0 indicating no connections with any actor (i.e. isolate) to 1.0 reflecting direct ties to everyone. Normalised degree centrality measures the extent to which an actor is involved in numerous relationships. Actors with high scores are the most visible participants in a network.'⁹ (Full details and explanations in Appendix C).

However, the application of each traditional centrality index separately has some drawbacks, such as the low degree of heterogeneity in the results of the application of the degree centrality to spatial networks. Therefore, new combined indexes have been created thanks to the collaboration with Sergi Lozano and Luce Prignano from the University of Barcelona.¹⁰ Taking as a starting point the degree centrality calculated on the road networks, which was the most successful, various combinations of indexes of centrality calculated for river and road networks have been tried, and the three best indexes have been selected. As will be shown in the following section this further analysis, which includes information about both the roads and the fluvial connections, gives results that are helpful only for the Bronze Age, but not useful, on average, for more recent ages. This confirms previous analyses which emphasised the importance of fluvial routes for the earliest period.

As with previous traditional network centrality indexes, the correlation between this newly defined quantity and settlement size (an independent indicator of centrality also used in the previous exploratory analysis) was explored through regression analysis. Finally, to provide further validation of the original working hypothesis, we estimated how many centres would have been identified as primary if there was no information at all (random hypothesis); in this way it was possible to assess the relevance of knowledge about rivers and terrestrial routes embedded in our index.

4.2 Discussion of the Analyses and Results

Systemic Approach

As explained in Section 4.1, betweenness centrality, closeness centrality and degree centrality were calculated for fluvial and terrestrial settlement networks in southern Etruria and Latium vetus from the Final Bronze Age to the Archaic Period and settlement predicted to be central by both those indexes and their sizes were calculated as percentage of all primary settlements in order to assess if there is a strong correlation between centrality predicted by size and centrality predicted by different network measures. Fig. 4.2 shows the values calculated for the degree centrality of the terrestrial route networks in Latium vetus as an example. In this case twenty-six settlements are central according to their size, and seventeen of these are also predicted to be central by degree centrality, calculated for the network modelled on terrestrial communication routes. The threshold of significance of network centrality was established empirically by observation, that is evaluating the degree of centrality of most of the primary settlements. For example, in the case illustrated in Fig. 4.2 the threshold is established around 0.05, which in this case corresponds also roughly to the Fisher rule, but this was not always the case. (All calculations are presented in Appendix C, and the thresholds identified for each case are detailed). In this case it means that about 67% of the settlements were predicted to be central both by their size and by the degree centrality. Such a percentage is generally considered more than acceptable when testing the efficacy of a model.

Fig. 4.3 shows the percentages of central places for southern Etruria and Latium vetus predicted to be central both by their size and by the different

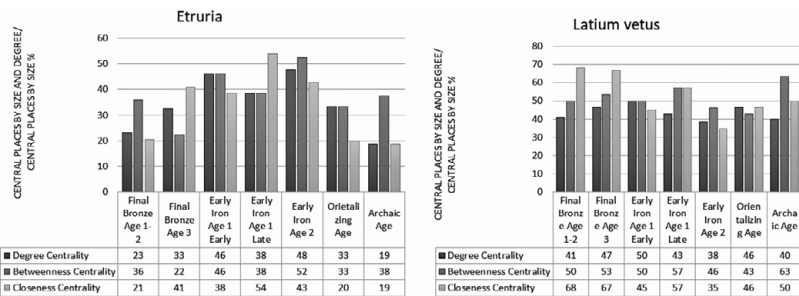


FIGURE 4.3. Percentage of central places predicted both by size and by degree on the total of central places predicted by size calculated for the fluvial networks of southern Etruria and Latium vetus from the Final Bronze Age to the Archaic Period.

centrality indexes calculated on fluvial networks between the Final Bronze Age and the Archaic Period. Data presented show that all three indexes seem able to predict relatively high degree centrality results for most sites predicted to be central also by their size. The normalised degree centrality seems to be able to indicate central sites that are also central by their size, slightly better than other indexes in both regions. The betweenness centrality also performs rather well.

This seems to indicate that in both Etruria and Latium vetus primary centres, or centres predicted to be central by their size receive goods/information easily, thanks to the relative high number of neighbours (degree centrality) and have good control over the flows of information/goods (betweenness centrality). However, they are also rather well connected to all other nodes (closeness centrality). It is important to note that both in Etruria and Latium vetus, all indices seem to perform better in the earlier phases than in later periods. This probably indicates the decreasing importance of fluvial connections, at least at the local intra-regional level, through time.

Fig. 4.4 shows the percentages of correctly predicted central places for southern Etruria and Latium vetus according to the different centrality indexes calculated for terrestrial routes networks between the Final Bronze Age and the Archaic Period. In this case, the centrality index that is most able to predict central places in the terrestrial networks, both in southern Etruria and Latium vetus, is the normalised degree centrality or the number of neighbours of each node, normalised on the size of the network (total number of nodes). The betweenness centrality and the closeness centrality in contrast work rather well in Latium vetus but not so well in southern Etruria, and their capacity to predict central places, that are also central by their size, seems to decrease with later periods.

This means the information and goods travelling on terrestrial routes quite easily reach the central places (degree centrality) in both southern Etruria and Latium vetus; however, central places are better connected to all other nodes of the system (closeness centrality) in Etruria in the earlier phases and in Latium vetus in the later phases. In addition, while central places in southern Etruria still have a certain control over the flow of information/goods through the system (betweenness centrality), this seems to be much stronger for the central places in Latium vetus.

However, probably the most interesting trend is that the percentages of centres predicted to be central, both by the three types of degree centrality and by their size, seem generally to increase with later phases for Latium and decrease for Etruria. Significantly this shift has also been noticed in the

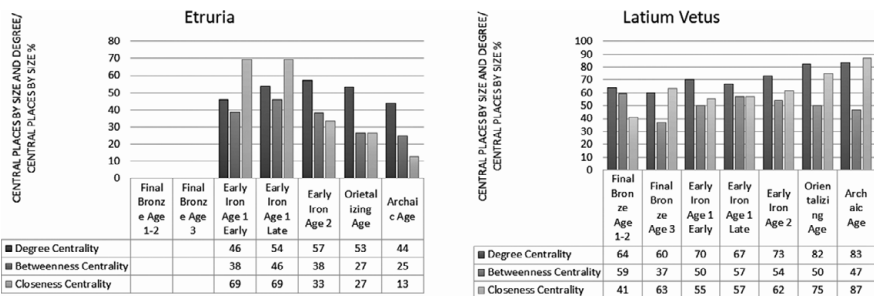


FIGURE 4.4. Percentage of central places predicted both by size and by degree of the total of central places predicted by size calculated for the terrestrial routes networks of southern Etruria and Latium vetus from the Final Bronze Age to the Archaic Period.

general historical and archaeological narrative of the two regions. A number of scholars have observed that the proto-urban phenomenon is slightly earlier and more dramatic in Etruria, where at least five or six large proto-urban centres between 100 and 200 ha (Veii, Tarquinia, Caere, Vulci, Bisenzio and Orvieto) are formed almost contemporarily by the end of the Final Bronze Age/beginning of the Early Iron Age. Later though the equilibrium between these centres become more and more difficult to maintain. In contrast, in Latium vetus, Rome emerges as a large, unified centre of about 200 ha only with the Latial Period IIA1/IIB, in Early Iron Age 1 Late, when it finally becomes comparable to Etruscan sites and dominant in the region. Finally, the rank-size analysis of the two regions, presented in earlier works,¹¹ and the efficiency indexes and the modelling presented later respectively in Chapters 5 and 7, also confirm this picture of power balance and dynamics in the two regions.

To better understand the relation between the centrality indexes and the size of the settlements (which is an indication of their importance) correlation coefficients between the centrality index settlement values and settlement sizes have been calculated for the fluvial networks and the terrestrial routes networks in the various periods in southern Etruria and Latium vetus. For example, Fig. 4.5 shows the graph of the correlation coefficient (R^2) between settlement size and the degree centrality calculated for terrestrial route networks in Latium vetus during the Early Iron Age 2. Firstly, the results of the different indexes for the different networks have been compared within each region, and secondly the two regions have been compared against each other.

Figs 4.6–4.8 compare the correlation between centrality indexes and size within each region respectively for fluvial networks and terrestrial networks. They confirm the analyses already presented above but add some detail. As

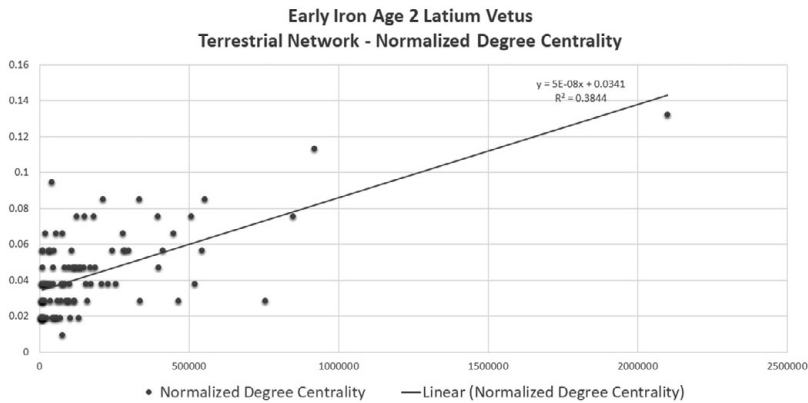


FIGURE 4.5. Correlation coefficient (R^2) between settlement size and the degree centrality calculated for terrestrial route networks in Latium vetus during the Early Iron Age 2.

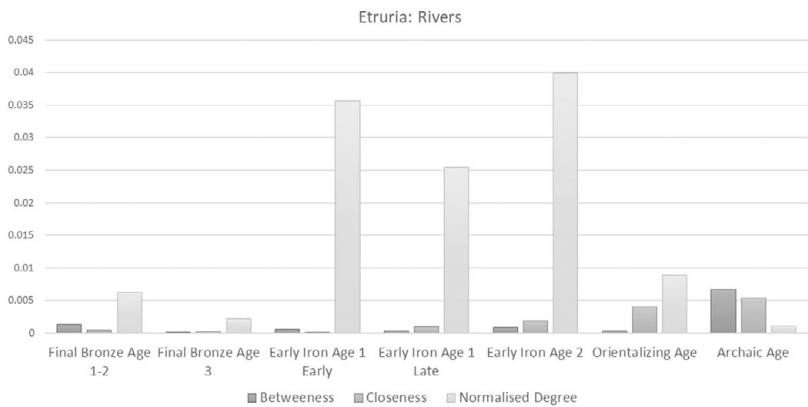


FIGURE 4.6. Values of the correlation coefficient (R^2) between settlement centrality indexes and settlement sizes for the river networks of Etruria from the Final Bronze Age to the Archaic Period.

already mentioned, the normalised degree centrality seems to have the stronger correlation to size for both regions for both types of network. The second best index to show a strong correlation with size for both rivers and terrestrial routes networks for both regions is the betweenness centrality. Finally, all three indexes show higher correlation with settlement size in both regions for the terrestrial routes especially during the Early Iron Age and later periods. As already mentioned, this seems to confirm the decreasing importance of fluvial communications and the increased impact of

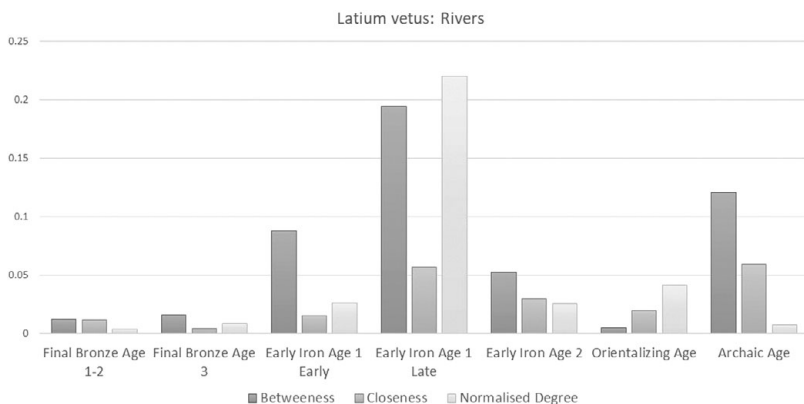


FIGURE 4.7. Values of the correlation coefficient (R^2) between settlement centrality indexes and settlement sizes for the river networks of Latium vetus from the Final Bronze Age to the Archaic Period.

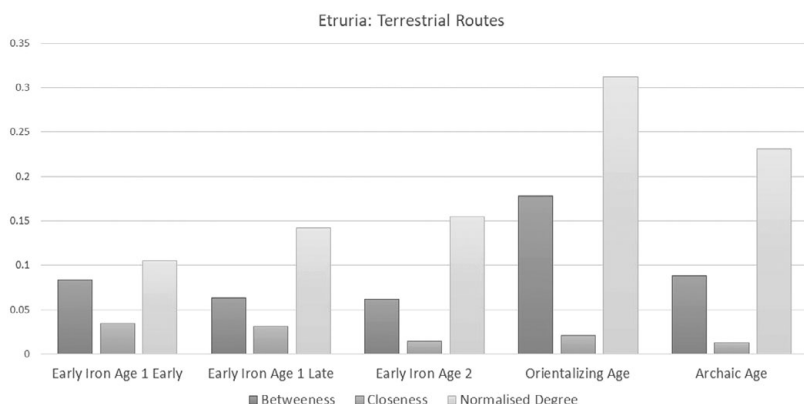


FIGURE 4.8. Values of the correlation coefficient (R^2) between settlement centrality indexes and settlement sizes for the terrestrial route networks of Etruria from the Final Bronze Age to the Archaic Period.

terrestrial routes for the development of proto-urban centres and later cities in central Italy from the Early Iron Age to the Archaic Period.

Looking more closely, however, in Latium vetus the correlation between centrality index values and settlement sizes is stronger during the Early Iron Age than the subsequent periods; for Etruria, the correlation between settlement size and normalised degree centrality and betweenness centrality grows from the Earliest phases of the Early Iron Age 1 to the Early Iron Age 2 and is even stronger in the Orientalising and Archaic

Period. This seems to indicate that terrestrial routes were instrumental in the flourishing of Latin central places as hubs of communication and/or exchange of information/goods more during the Early Iron Age while in Etruria they acquired a greater importance only in the subsequent periods (Fig. 4.9).

When the values of the correlation between settlement size and centrality index for the different networks are compared between the two regions, further details are revealed. Figs 4.10–4.12 show the correlation between

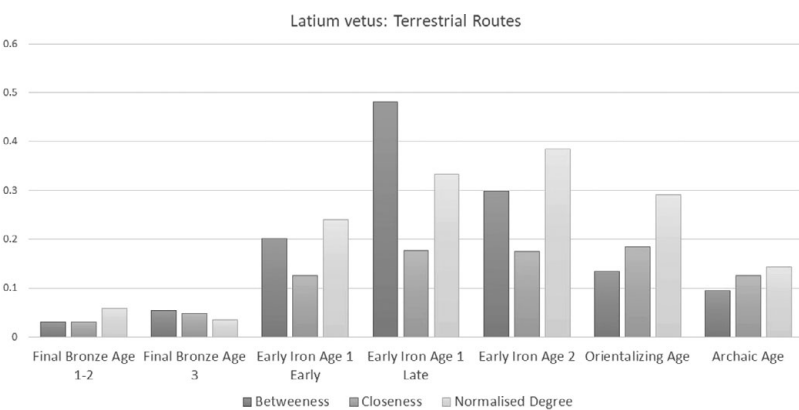


FIGURE 4.9. Values of the correlation coefficient (R^2) between settlement centrality indexes and settlement sizes for the terrestrial route networks of Latium vetus from the Final Bronze Age to the Archaic Period.

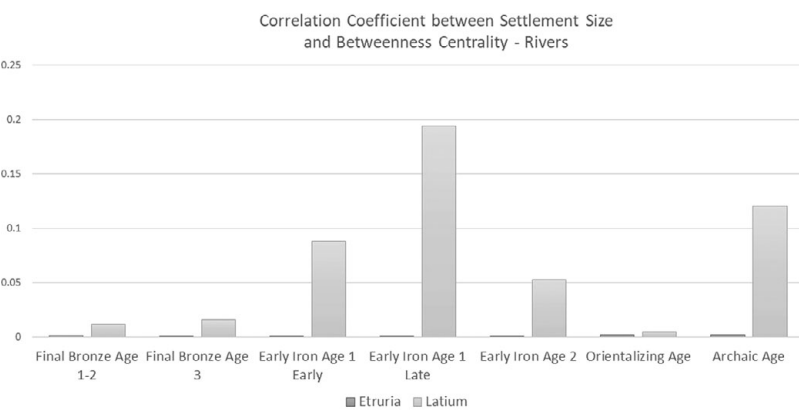


FIGURE 4.10. Values of the correlation coefficient (R^2) between settlement centrality indexes and settlement sizes for the fluvial networks of southern Etruria and Latium vetus from the Final Bronze Age to the Archaic Period: betweenness centrality.

settlement centrality indexes and settlement sizes calculated on the fluvial communication networks in southern Etruria and Latium vetus between the Final Bronze Age and the Archaic Period. The diagrams show that the networks seem to be much more efficient in Latium vetus than in Etruria in terms of accessibility of information and goods to the central places (degree centrality), connectivity of the central places to all other nodes in the system (closeness centrality) and control of the central places over the flow of information/goods through the system (betweenness centrality).

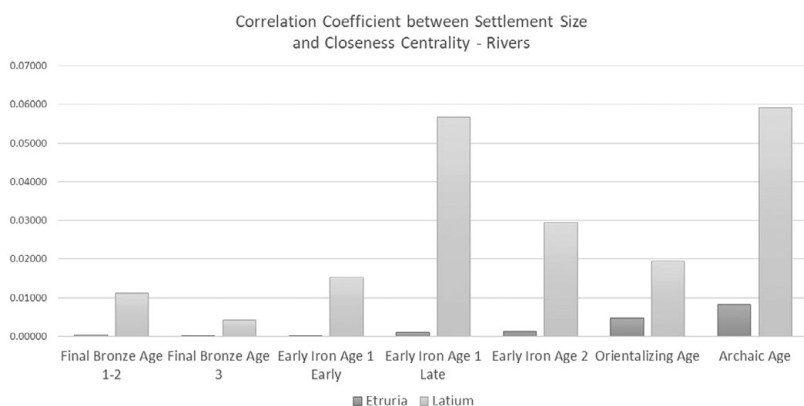


FIGURE 4.11. Values of the correlation coefficient (R^2) between settlement centrality indexes and settlement sizes for the fluvial networks of southern Etruria and Latium vetus from the Final Bronze Age to the Archaic Period: closeness centrality.

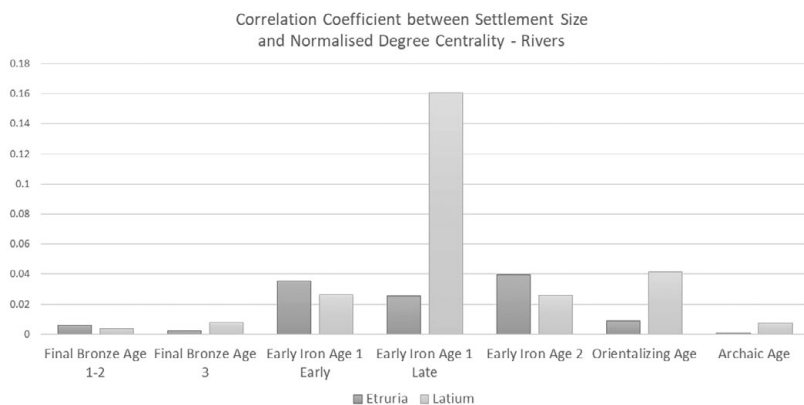


FIGURE 4.12. Values of the correlation coefficient (R^2) between settlement centrality indexes and settlement sizes for the fluvial networks of southern Etruria and Latium vetus from the Final Bronze Age to the Archaic Period: normalised degree centrality.

The correlation is strong for all the three indexes during the Early Iron Age 1 Late and for the betweenness centrality and closeness centrality also in the Archaic Period.

I wonder if this happens just by chance that these two periods are particularly important in the development of Rome as a growing centre and power. The Early Iron Age 1 Late or the Latial Period IIB is the time when Rome grows dramatically from a probably polynuclear medium-size settlement to a very large unified settlement of about 200 ha and when the first secondary settlements around Rome are founded; the Archaic period is the time when the pomerium is enlarged,¹² a new fortification wall is built to encompass an area of more than 400 ha and Rome extends its domination over the whole Latium vetus.

When terrestrial communications routes are considered (Figs 4.13–4.15), the advantage of Latium vetus is not so absolute. The correlation coefficient between the closeness centrality index and settlement sizes seem to show that Latin central places are better connected to all other nodes in the system than Etruscan central places in all periods considered. As mentioned earlier, this might be obvious in a smaller and more compact region such as Latium vetus. In contrast, the correlation coefficient between respectively settlement degree centrality and betweenness centrality and settlement size is stronger in Latium vetus only for the Early Iron Age, while it is almost equal in the two regions for the Orientalising and the Archaic Period, with even with a small advantage of Etruria over Latium

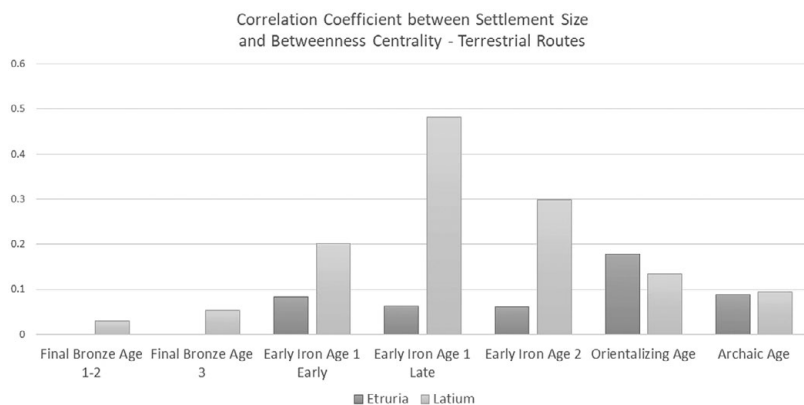


FIGURE 4.13. Values of the correlation coefficient (R^2) between settlement centrality indexes and settlement sizes for the terrestrial route networks of southern Etruria and Latium vetus from the Final Bronze Age to the Archaic Period: betweenness centrality.

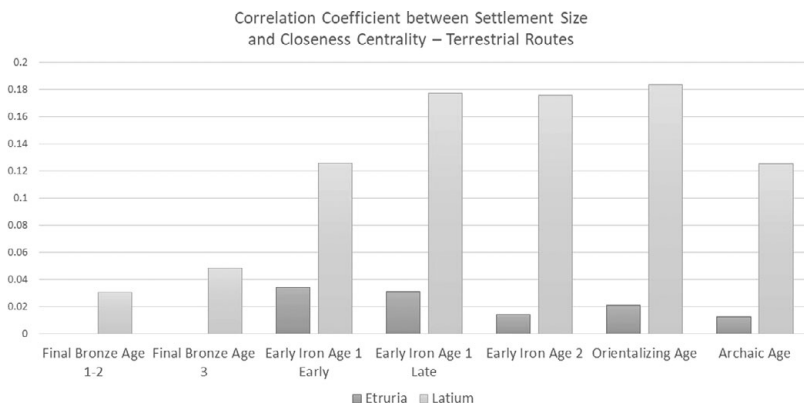


FIGURE 4.14. Values of the correlation coefficient (R^2) between settlement centrality indexes and settlement sizes for the terrestrial route networks of southern Etruria and Latium vetus from the Final Bronze Age to the Archaic Period: closeness centrality.

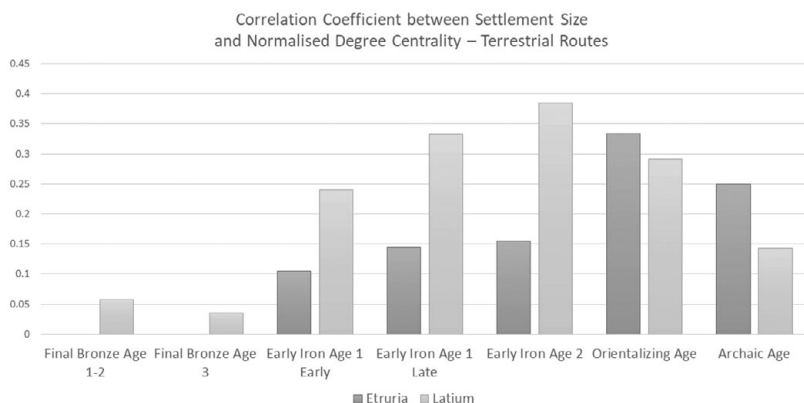


FIGURE 4.15. Values of the correlation coefficient (R^2) between settlement centrality indexes and settlement sizes for the terrestrial route networks of southern Etruria and Latium vetus from the Final Bronze Age to the Archaic Period: normalised degree centrality.

vetus. For the Final Bronze Age, a comparison is not possible because of the lack of information on terrestrial routes in southern Etruria.

This seems to indicate that the access to information/goods (degree centrality) is easier for Latin central places in the early Iron Age; and the control over the flow of information/goods (betweenness centrality) is stronger for Latin central places in the same period, while the situation is reversed for the Orientalising and Archaic Age even if the advantage of

Etruria in these period is much lower. This seem to indicate that in the Early Iron Age terrestrial routes were more important for the success of Latin proto-urban centres as central places for the flow and diffusion of goods and information rather than for Etruscan centres, while in the Orientalising and Archaic Age the situation is closely similar in both regions.

As anticipated in Section 4.1 on methodology and illustrated in detail by all calculations in Appendix C, a more robust method was also used to test the correlation between centres predicted to be central by their size (proxy of political and economic importance) and centres predicted to be central by the different centrality indexes. In particular, the confusion matrix has been adopted to evaluate the performance of the classification models. The matrix (table) shows us the number of correctly and incorrectly classified examples, compared to the actual outcomes (target values) in the test data. One of the advantages of using a confusion matrix as an evaluation tool is that it allows more detailed analysis (such as if the model is confusing two classes), than simple proportion of correctly classified examples (accuracy) which can give misleading results if the dataset is unbalanced (e.g. when there are huge differences in numbers within classes or between different classes).

The prediction or confusion matrix tests predictions and correlations in complex matrices with the use of a logic table that cross-tabulates predicted and observed examples using four options:

True Positive (TP): Correctly predicting a label (we predicted 'yes', and it's 'yes').

True Negative (TN): Correctly predicting the other label (we predicted 'no', and it's 'no').

False Positive (FP): Falsely predicting a label (we predicted 'yes', but it's 'no').

False Negative (FN): Missing label (we predicted 'no', but it's 'yes').

A series of measures, illustrated in Appendix C, allow evaluation of the performance of the model. We are particularly interested in the *precision*, which indicates the positive predictive value, the *false positive rate* and the *false discovery rate*, and the *accuracy*. These measures are illustrated in Figs. 4.16 and 4.17.

The accuracy of the predictions is generally high for all matrices both for river networks and terrestrial routes networks for all different types of centrality indexes. Similarly to previous analyses, the normalised degree centrality seems to provide the best predictions both in Etruria and Latium

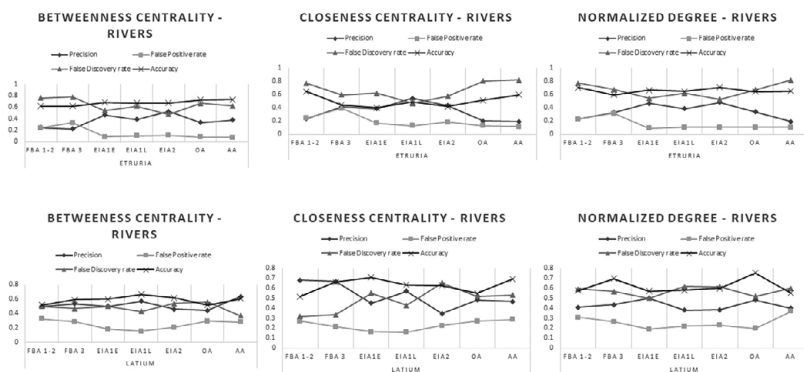


FIGURE 4.16. Evaluation through the confusion matrix presented in Appendix C, of the correlation between centres predicted to be central by their size and centres predicted to be central by centrality indexes. River networks.

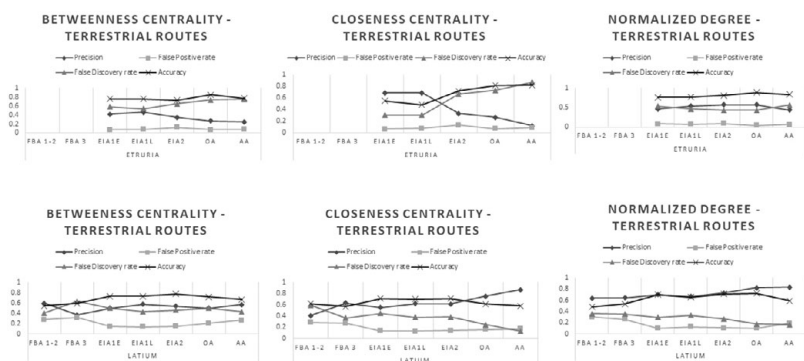


FIGURE 4.17. Evaluation through the confusion matrix presented in Appendix C, of the correlation between centres predicted to be central by their size and centres predicted to be central by centrality indexes. Terrestrial routes networks.

vetus and both for rivers and terrestrial communication routes. In general, the prediction of the river networks seems to work less well than terrestrial routes and have a decreasing trend from the Bronze Age to more recent periods, while the terrestrial routes show an increasing trend especially for Latium vetus. In Etruria, in contrast, both the betweenness centrality and the closeness centrality show decreasing trends both for river routes and terrestrial routes. As we have partially seen already and will see in Chapter 5, terrestrial routes seems to have greater importance during the Iron Age rather than the Bronze Age and Latium vetus seems slightly more efficient than Etruria.

As mentioned in Section 4.1, considering traditional network centrality indexes alone has some drawbacks. Therefore, new combined indexes, developed in collaboration with Sergi Lozano and Luce Prignano, have been considered, as described in Section 4.1. Fig. 4.18 shows the percentages of settlements correctly predicted to be central by the combined indexes (I₁, I₂ and I₃) and in the random case (R) in comparison with settlements predicted to be central by their size in Latium vetus between the Final Bronze Age and the Archaic Period. In general, the number of correctly predicted sites increases with later periods because all combined indexes are based mainly on the degree centrality network of terrestrial routes, which we have seen before was the most successful one in predicting the development of proto-urban centres and cities both in Latium vetus and Etruria.

It also shows that when we add information about fluvial networks, they only seem to make a difference for the Final Bronze Age 1–2 (I₂) and the Final Bronze Age 3 (I₃) and partially for the Archaic Period (again I₃). This seems to confirm previous studies that detected a greater importance of vicinity to rivers and importance of rivers as local communication means of transport and communication more during the Bronze Age rather than in the Iron Age when it is probable that carts start to be more widespread and terrestrial routes become more important. The validity of these results has been confirmed by the comparison with the case of a random hypothesis which shows significantly different results. When we consider the correlation coefficient between settlements predicted to be central by their size and by the three indexes (Fig. 4.19), as for previous results, the highest value for Latium vetus are in the Early Iron Age.

Ego-Network Approach

Finally, most important early Iron Age proto-urban centres in southern Etruria and Latium vetus have also been considered individually and their centrality indexes have been compared through time both for the fluvial and the terrestrial route networks. When the fluvial communication networks are considered in accordance with previous results the Latin centres, such as Rome and Gabii, seem to be better connected to all other centres in the system (closeness centrality, Fig. 4.20) than the central places in southern Etruria. When considering the accessibility to information thanks to higher number of connections (degree centrality, Fig. 4.21) Rome, Veii, Vulci and partially Tarquinia and Gabii seem to have the greater number of connections via fluvial routes. However, Rome, Veii and Vulci seem to

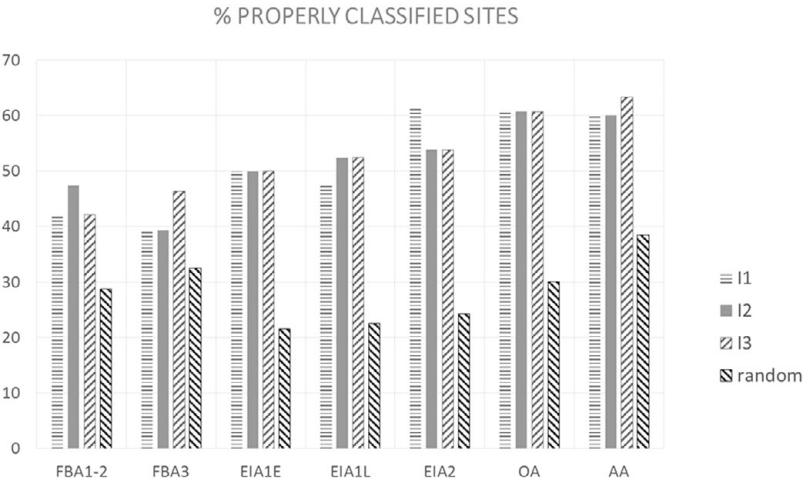


FIGURE 4.18. Percentages of settlements correctly predicted to be central by the combined indexes (I1, I2 and I3) and in the random case (R) in comparison with settlements predicted to be central by their size in Latium vetus between the Final Bronze Age and the Archaic Period.

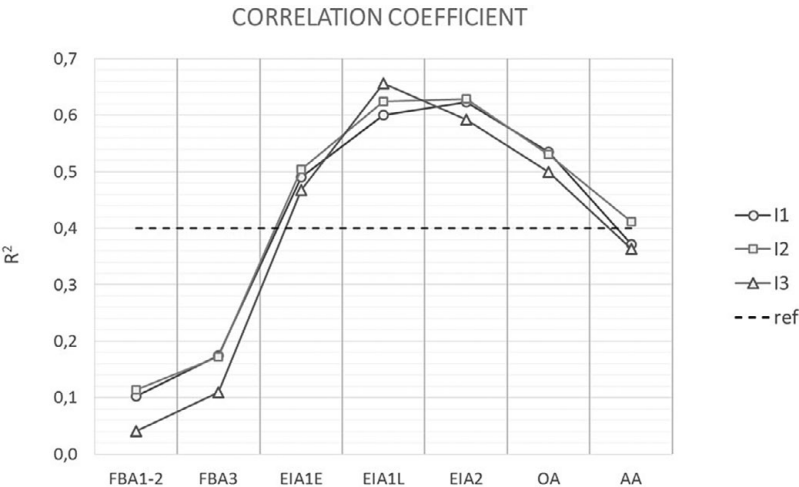


FIGURE 4.19. Values of the correlation coefficient (R^2) between settlement centrality indexes and settlement sizes for the terrestrial route networks of southern Etruria and Latium vetus from the Final Bronze Age to the Archaic Period.

have smaller access to goods/information through the number of their neighbours in the Orientalising and Archaic Period than in the Early Iron Age. When considering the control over the flow of information/goods (betweenness centrality, Fig. 4.22), it is interesting to note how Veii and

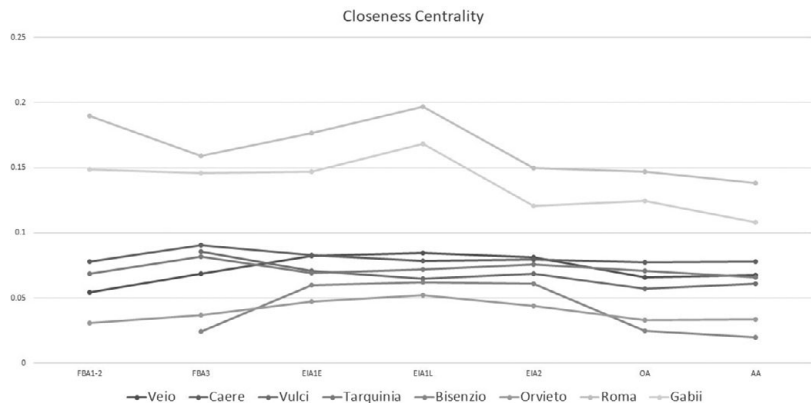


FIGURE 4.20. Comparisons of the centrality index values calculated on the fluvial networks for central places larger than 80 ha in southern Etruria and Latium vetus from the Final Bronze Age to the Archaic Period: closeness centrality.

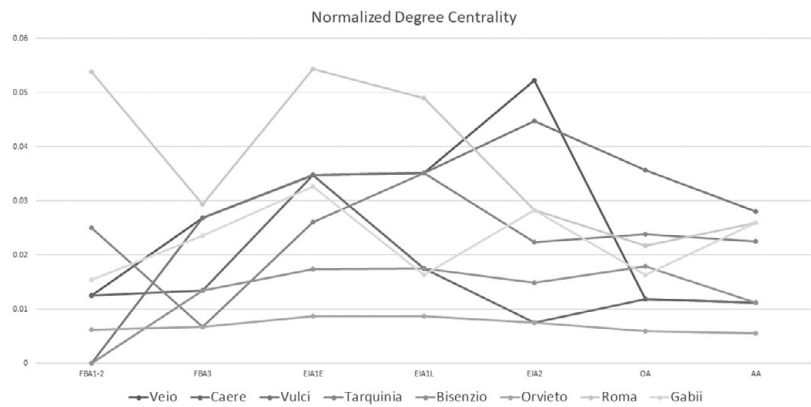


FIGURE 4.21. Comparisons of the centrality index values calculated on the fluvial networks for central places larger than 80 ha in southern Etruria and Latium vetus from the Final Bronze Age to the Archaic Period: normalised degree centrality.

Rome have very similar trends which correspond to the traditional idea of the two centres as sort of specular centres in the two regions. They also have the highest score in all the periods with a drop in the Orientalising Period.

Looking at the terrestrial communications networks and the potential of the individual central places, the Latin centres of Rome and Gabii show a clear advantage in the connectivity to all other centres in the system (closeness centrality, Fig. 4.23) and in the accessibility to goods/information

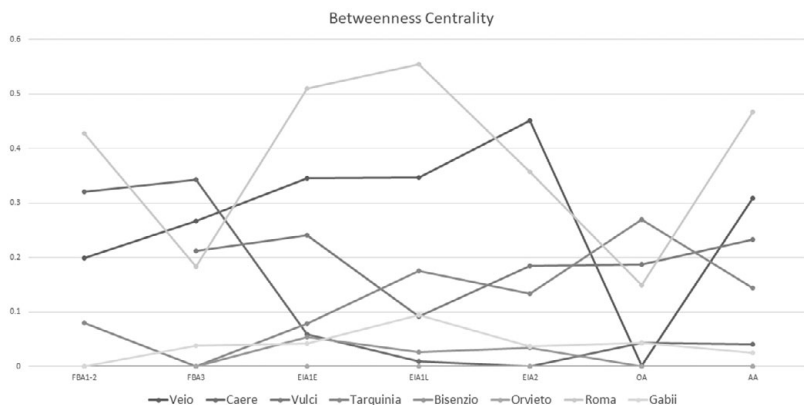


FIGURE 4.22. Comparisons of the centrality index values calculated on the fluvial networks for central places larger than 80 ha in southern Etruria and Latium vetus from the Final Bronze Age to the Archaic Period: betweenness centrality.

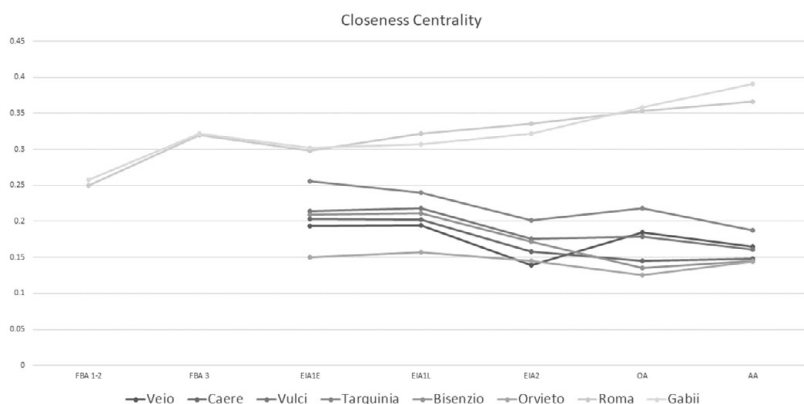


FIGURE 4.23. Comparisons of the centrality index values calculated on the terrestrial route networks for central places larger than 80 ha in southern Etruria and Latium vetus from the Final Bronze Age to the Archaic Period: closeness centrality.

via the mean of neighbours (degree centrality, Fig. 4.24). The betweenness centrality (Fig. 4.25), which indicates the control over the flow of goods/information, is higher for Rome and Gabii in the Early Iron Age 1, declines in the Early Iron Age 2 and rises again for Gabii in the Archaic period but not for Rome. Veii and Tarquinia have a marked rise in the betweenness centrality during the Orientalising period.

It is interesting to note that while the betweenness degree of Rome declines during the Orientalising and Archaic Period both for the river and

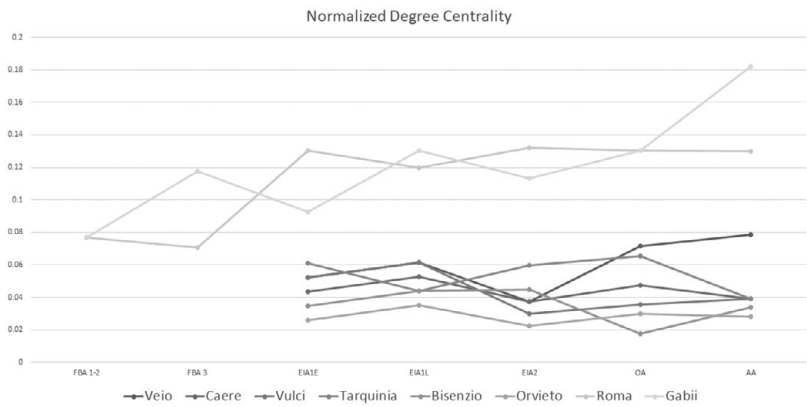


FIGURE 4.24. Comparisons of the centrality index values calculated on the terrestrial route networks for central places larger than 80 ha in southern Etruria and Latium vetus from the Final Bronze Age to the Archaic Period: normalised degree centrality.

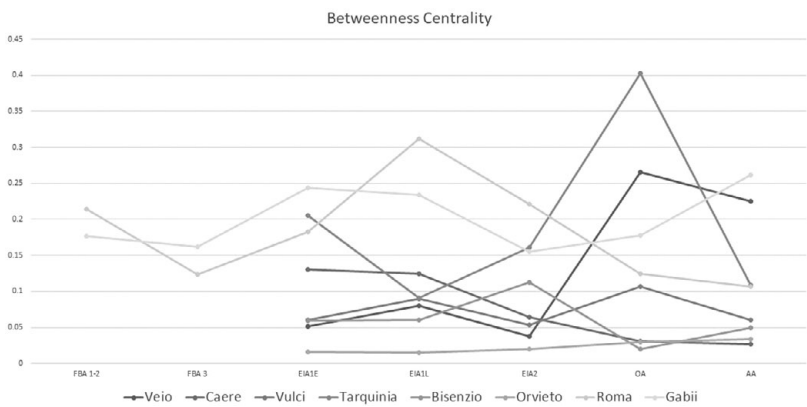


FIGURE 4.25. Comparisons of the centrality index values calculated on the terrestrial route networks for central places larger than 80 ha in southern Etruria and Latium vetus from the Final Bronze Age to the Archaic Period: betweenness centrality.

terrestrial routes networks, the same degree increases greatly for the secondary sites present within its territory and most probably controlled by it, sites such as Sito Eur, La Rustica, Acqua Acetosa, Antemnae, Castel di Decima, Ponte Mammolo and La Rustica, especially for the fluvial networks in the Archaic Period. This seems to indicate growing importance of the connectivity and development of secondary settlements, and of the countryside which will continue and have important consequences for the Roman economy especially in the Republican and Imperial Period (Table 4.1).¹³

TABLE 4.1. *Betweenness centrality of Latin Sites in rivers and terrestrial routes networks in the Orientalising Age (A) and Archaic Period (B)*

A Orientalising period					
vertexid	settlement	Size	Area	Betweenness centrality – rivers	Betweenness centrality – terrestrial routes
1	Roma	1.00000	2745154	0.149701386	0.124539224
2	Sito dell'EUR	1.00000	1467048	0.152846791	0.063860067
3	Gabii	1.00000	918782	0.043239369	0.177961461
4	Ardea	1.00000	848969	0.02173913	0.130593113
5	Alba	1.00000	756100	0.071114031	0.002498473
6	Ponte Mammolo	2.00000	654755	0.182947125	0.037601348
7	Ficulea	2.00000	552989	0.13828237	0.034098749
8	C. della Coedra-Cora	2.00000	542885	0.02173913	0.021162452
9	Crustumium	2.00000	519072	0.010869565	0.000569222
10	Satricum	2.00000	507406	0.248702023	0.094012872
11	Cisterna di Latina	3.00000	448530	0.146201624	0.034957133
12	Fidenae	3.00000	413473	0.029741997	0.003019449
13	Valmontone-Tolerium	3.00000	394611	0	0.045850487
14	Casale C.-Cameria	3.00000	340978	0.032361841	0.036359213
15	Corcolle	3.00000	335871	0.103917821	0.02356744
16	Lavinium	3.00000	334476	0.337060041	0.036194261
17	Bovillae	3.00000	298673	0.003901895	0.047098216
18	Velletri	3.00000	287060	0.02173913	0.049908106
19	Tivoli	3.00000	280989	0.103917821	0.059722103
20	Lunghezza-Collatia	3.00000	279314	0.373387482	0.102714219
21	Ficana-M. Cugno	3.00000	254142	0.007007485	0.002066786
22	Palestrina	3.00000	242783	0.000119446	0.0126548
23	T. Torrino-Politorium?	3.00000	229770	0.157234432	0.009816516
24	Tellenae	3.00000	213244	0.019652811	0.308142519
25	S. Giovanni in C.	3.00000	208097	0	0.052211986
26	Nomentum	3.00000	186019	0.002388915	0.01969294
27	M. Giove-Corioli	3.00000	181672	0	0.181235825
28	Antemnae	4.00000	171677	0.171544036	0.007459413
29	C. della Fragola	4.00000	168931	0	0.006842287
30	S. Angelo Romano	4.00000	160340	0	0.001656315
31	Montecelio	4.00000	154154	0.02173913	0.006445337
32	Colonna-Labici?	4.00000	150889	0	0.083744055

Table 4.1. (cont.)

A Orientalising period					
vertexid	settlement	Size	Area	Betweenness centrality – rivers	Betweenness centrality – terrestrial routes
33	Anzio	4.00000	148145	0.034241121	0.029375878
34	Lanuvio	4.00000	136270	0.049124064	0.061125007
35	Poli-Bola?	4.00000	133217	0.010750119	0.043151367
36	Tuscolo	4.00000	125053	0	0.002006508
92	Labico-Bola?	4	117855	0.215209428	0.05123466
37	Colli S. Stefano	4.00000	116873	0	0
38	Ariccia	4.00000	116575	0.028591336	0.046277371
39	Campo del Fico	4.00000	114914	0.338652652	0.001030126
40	Castel di Decima	4.00000	111950	0.391260551	0.046061971
41	Tenuta Trafusa	4.00000	100629	0.004658385	0.000557414
93	Buon Riposo-Longula	4	97877	0.010750119	0.007082375
42	Torre S. Anastasio	4.00000	97183	0.070226151	0.008368656
43	C. del Vescovo	4.00000	89373	0.043000478	0.001800534
44	C. delle Crocette	4.00000	83952	0.046934225	0.00297464
45	M. S. Angelo in Arcese	4.00000	83726	0	0.03212424
46	C. Lepre	4.00000	77492	0	0.028453418
47	M. Savello	4.00000	76354	0.042725753	0.035152469
48	Borgo Sabotino-s.s.a.	4.00000	76167	0.160535117	0
49	M. Carnale	4.00000	75091	0.054825609	0.008022105
50	Le Cese	4.00000	71449	0	0.002850066
51	Albano Laziale	4.00000	69307	0	0.014007747
52	Porta Neola	4.00000	61141	0	0.01340444
53	M. Cavo	4.00000	56648	0.077691511	0
54	L'Altare	4.00000	55973	0.22627807	7.96305E-05
91	S. Gallicano-Pedum	4	50000	0.009798535	0.029502816
55	Castelgandolfo	5.00000	48046	0.247523491	0
56	Passerano	5.00000	47025	0.084925944	0.04510691
57	C. Rotondo	5.00000	46801	0	0.0131003
58	Tor de Cenci	5.00000	45939	0.141650741	0.010319959
59	C. Fiorito	5.00000	45579	0.143573817	0.01826781
60	Castellaccio	5.00000	44513	0	0.073284899
61	C. Ripoli	5.00000	42162	0.063784042	0.005846601
62	La Rustica	5.00000	40769	0.414759516	0.094914874
63	M. Artemisio	5.00000	37126	0	0.015840572
64	C. Tasso	5.00000	35141	0.160535117	0.025184162

Table 4.1. (cont.)

A Orientalising period					
vertexid	settlement	Size	Area	Betweenness centrality – rivers	Betweenness centrality – terrestrial routes
65	M. dei Ferrari	5.00000	34593	0	0.050395337
66	M. Crescenzio	5.00000	32255	0.27523491	0.05446756
67	Sorgente Preziosa	5.00000	29762	0.344887721	0.005391392
68	Maschio d'Ariano	5.00000	28326	0.02173913	0.025117202
69	Casale della Perna	5.00000	23361	7.96305E-05	0.001680318
70	A.A. Laurentina	5.00000	20194	0.019772257	0.049205603
71	C. Cesarano	5.00000	18787	0.143573817	0.029039514
72	Galloro-M. Gentile	5.00000	17208	0.066985189	0.003226381
73	La Pasolina	5.00000	14901	0	0
74	M. Arcese	5.00000	10755	0.02173913	0.014095892
80	Villa Maldura	5.00000	10000	0.35814222	0.040623507
87	Orti Torlonia	5.00000	10000	0.24660774	0.038421532
79	Torre Astura	5.00000	10000	0.185865584	0.033047827
88	Prato della Corte	5.00000	10000	0.100768434	0.025132252
82	Pozzo Carpino	5.00000	10000	0.085861602	0.021941273
90	Casal Bruciato	5.00000	10000	0.075852047	0.015052392
83	Pescaccio	5.00000	10000	0.073025163	0.014385468
89	Paluzzi	5.00000	10000	0.057111005	0.007489208
81	Tor delle Streghe	5.00000	10000	0.043239369	0.007154009
84	Vallericcia-Via di M.	5.00000	10000	0.02998487	0.005287027
77	Cretarossa	5.00000	10000	0.021627648	0.002376971
78	Pelliccione	5.00000	10000	0.011036789	0.001303161
85	Marco Simone L. A	5.00000	10000	0	0.000708493
86	Le Caprine	5.00000	10000	0	0.000477783
75	Monteripoli	5.00000	8618	0.084089823	0.031078499
76	C. Ripoli-bis	5.00000	7959	0.043000478	0.01338632
B Archaic Period					
vertexID	settlement	Size	Area	Betweenness centrality – rivers	Betweenness centrality – roads
1	Roma	1	3650000	0.46650718	0.106598689
2	Sito dell'EUR	1	1467048	0.46753247	0.033777953
3	Gabii	1	918782	0.02494874	0.261695673

Table 4.1. (cont.)

B Archaic Period					
vertexID	settlement	Size	Area	Betweenness centrality – rivers	Betweenness centrality – roads
4	Ardea	1	848969	0.06772613	0.09263119
5	Alba	1	756100	0.03212577	0.025305166
6	Ponte Mammolo	2	654755	0.45659604	0.007592234
7	Ficulea	2	552989	0.12423103	0.040481074
8	S. Maria delle M.-Mugilla?	2	537649	0.07256778	0.000196403
9	Crustumium	2	519072	0	0.015633041
10	Satricum	2	507406	0.20557075	0.059767704
11	Cisterna di Latina	2	448530	0.11927546	0.04203895
12	Fidenae	3	413473	0.04955571	0.004095889
77	Gallicano	3	397783	0.01230349	0.038345032
14	Valmontone-Tolerium	3	394611	0.02494874	0.034406803
13	Macchia di Giulianello	3	394611	0	0
15	C. Capobianco-Cameria	3	340978	0.04613807	0.053406491
16	Corcolle	3	335871	0.11790841	0.024764869
17	Lavinium	3	334476	0.31447938	0.042330316
18	Rocca Priora-Corbio	3	317337	0	0.009683644
19	Bovillae	3	298673	0.07000456	0.075690506
20	Velletri	3	287060	0.02494874	0.039234367
21	Tivoli	3	280989	0.11790841	0.086075656
22	Lunghezza-Collatia	3	279314	0.35543404	0.052798449
23	Ficana-M. Cugno	3	254142	0.33242196	0.009296016
24	Palestrina	3	242783	0.00017088	0.009553382
25	T. Torrino-Politorium?	3	229770	0.39154705	0.025191558
26	Tellenae	3	213244	0.09102301	0.201136892
27	S. Giovanni in C.	3	208097	0	0.055325102
28	R. Massima-Carventum	3	191863	0	0.013268526
29	M. Giove-Corioli	3	181672	0.04972659	0.117372881
30	Antemnae	4	171677	0.49658237	0.021460604
31	M. Fiore	4	168025	0	0.058130932
32	S. Angelo Romano	4	160340	0	0.004902764
33	Montecelio	4	154154	0	0.00801511

Table 4.1. (cont.)

B Archaic Period					
vertexID	settlement	Size	Area	Betweenness centrality – rivers	Betweenness centrality – roads
34	Colonna-Labici?	4	150889	0	0.054152399
35	Anzio	4	148145	0.02358168	0.029324541
36	Lanuvio	4	136270	0.04180907	0.010184109
37	Poli-Bola	4	133217	0.01230349	0.052854586
38	Tuscolo	4	125053	0.02494874	0.137764989
75	Marino	4	121432	0	0.037584246
39	C. Rotondo	4	120000	0	0.000227842
40	Colli S. Stefano	4	116873	0	0.019678102
41	Ariccia	4	116575	0.04910002	0.055870777
42	Campo del Fico	4	114914	0.36369332	0.015811268
43	Castel di Decima	4	111950	0.05348599	0.0267978
44	Tenuta Trafusa	4	100629	0.01879699	0.00108579
76	Buon Riposo	4	97877	0.20950103	0.027924028
45	Torre S. Anastasio	4	97183	0.06390977	0.002952389
46	C. del Vescovo	4	89373	0.02494874	0.002137499
47	Rupe di S. Paolo	4	86213	0.46753247	0.001057289
48	M. S. Angelo in Arcese	4	83726	0	0.048745769
49	C. Lepre	4	77492	0	0.077530342
50	M. Carnale	4	75091	0.04955571	0.016932089
51	Buglioncino	4	67025	0	0.025884662
52	Porta Neola	4	61141	0.16233766	0
53	Forte Ostiense	4	59320	0.46787423	0.004158468
78	M. Cavo	4	56648	0	0.000113921
54	Castelgandolfo	5	48046	0.00558214	0.05727694
55	Passerano	5	47025	0.09688995	0.015870045
56	Tor de Cenci	5	45939	0.06168831	0.002919796
57	C. Fiorito	5	45579	0.18045113	0.035362014
58	Trigoria	5	44522	0.03503076	0.006965422
59	C. Ripoli	5	42162	0.07279563	0.003877098
60	La Rustica	5	40769	0.04921394	0.11067427
61	M. Artemisio	5	37126	0	0.00703326
62	Casal Boccone	5	34977	0.4550581	0.003247833
63	M. dei Ferrari	5	34593	0	0.028384678
64	Casale Redicicoli 2	5	29425	0	0.000938566
65	Maschio d'Ariano	5	28326	0	0.019095019
66	A.A. Laurentina	5	20194	0.11016177	0.042953704

Table 4.1. (cont.)

B Archaic Period					
vertexID	settlement	Size	Area	Betweenness centrality – rivers	Betweenness centrality – roads
67	C. Cesarano	5	18787	0.32091593	0.00806555
68	M. Arcese	5	10755	0.02494874	0.019354024
74	Casal Bruciato	5	10000	0.02631579	0.047466143
72	Pelliccione	5	10000	0.00803144	0.014583713
71	Cretarossa	5	10000	0.00580998	0.006857869
73	Le Caprine	5	10000	0	0.000580998
69	Monteripoli	5	8618	0.09569378	0.031226974
70	C. Ripoli-bis	5	7959	0.04921394	0.009813574

4.3 Conclusions

When considering the potential of network centrality indexes to correctly predict the ‘centrality’ or importance of historical and archaeological central places, indicated by their size as a proxy, the degree centrality seems to be able to capture this quality best, both in relation to fluvial and terrestrial communication networks in both regions. This seems to indicate that central places both in Etruria and Latium vetus had easy access to information and goods thanks to their large number of neighbours. In Latium vetus the three indexes seem to predict central places better than in Etruria for both the fluvial and the terrestrial routes networks. That means that probably central places in Latium vetus not only had easy access to information/goods (degree centrality) but also had a certain amount of control over the flow of information (betweenness centrality) and were well connected to all other nodes in the system (closeness centrality). For the Bronze Age we do not have data on the terrestrial routes in Etruria, but for the fluvial routes the three indexes seem to predict central places better in the Bronze Age rather than in the Iron Age. In Latium vetus, similarly terrestrial routes seem to be more important during the Iron Age and later periods.

When considering the correlation between settlements predicted to be central by their size and by the three traditional centrality indexes and comparing fluvial networks to terrestrial route networks, some more details emerge in the interpretation. Both in Etruria and Latium vetus, terrestrial

routes seem to be more important than fluvial routes in the development of proto-urban centres as central places especially in the Early Iron Age and later periods. When the two regions are compared with each other, for fluvial communication networks the correlation is generally higher for Latium vetus rather than Etruria, especially for the Early Iron Age 1 late (all three indexes) and for the Archaic Period (closeness centrality and betweenness centrality). For the terrestrial route communication network, the correlation is distinctively higher in Latium vetus for the Early Iron Age but is almost equal or even slightly reverse (higher for Etruria) in the Orientalising and Archaic Age.

This seems to indicate that terrestrial communication routes were generally more important in the development of Latin and Etruscan proto-urban centres and cities than fluvial communication routes. However, fluvial communication routes played an important complementary role in Latium vetus, especially late in the Early Iron Age 1 and in the Archaic period. When centrality predicted by centrality measures and centrality predicted by size are correlated, the *R* correlation coefficient seems to indicate that the Latin system had a slight advantage in the earliest phases, while the confusion matrix seems to indicate that the advantage of the Latin region grows with time and the importance of the terrestrial system decreases importance for the centrality of the Etruscan centres with time. In Chapter 5, we will analyse more specifically the efficiency of the infrastructure of the two regions, which will shed further light on this specific issue. When a more robust centrality index is built to analyse terrestrial and fluvial networks in Latium vetus, it shows more clearly that fluvial communications routes were probably more important in the Final Bronze Age rather than in the Early Iron Age, when terrestrial routes became more important.

When considering the major Etruscan and Latin Early Iron Age proto-urban settlements in their individuality, Rome generally shows amongst the highest scores for all the indexes in both the terrestrial and fluvial networks. However, in many of them Gabii has also similar scores. In general, it seems that the advantage of Rome is not on an absolute individual optimisation of its performance but more on a systemic level. It is not the most favoured site in absolute terms, but it is the dominant centre in Latium vetus, which, as a system, has some advantages over Etruria.

To conclude, the analysis of centrality measures calculated on fluvial and terrestrial communication routes in Etruria and Latium vetus seemed to indicate that in Latium vetus the development of central places is linked strongly to the development of infrastructural facilities, especially terrestrial

routes. It is not possible to establish from the simple observation of this correlation a cause–effect link: that is to understand if in Latium the centres which are more central to the networks grow more, or on the contrary, if the centres which grow more develop more links. Most likely it is a reciprocal process that determines co-evolution of infrastructures and urban centres. It is rather clear though that the two elements are not linked so distinctively and to the same degree in southern Etruria.

CHAPTER 5

Network Analysis Efficiency Indexes

5.1 Methodology

As we have seen in Section 1.2 of Chapter 1, between the Final Bronze Age and the beginning of the Early Iron Age, southern Etruria and Latium vetus underwent important processes of centralisation and nucleation of the settlement system that led to the formation of large proto-urban centres. These eventually evolved into cities during the end of the Early Iron Age, the Orientalising Age and the Archaic Period. A graph representing the trend of median settlement size in southern Etruria and in Latium vetus through time, shows how the two regions had a similar beginning and parallel development with different final outcomes (Fig. 5.1). Is it possible to explain the reason for this final result? Were the initial situations after all so similar? In Chapter 4, by analysing centrality measures calculated on the fluvial and terrestrial networks of the two regions we emphasised some similarities and differences. In this chapter we focus further on the infra-structural systems of the two regions (fluvial and terrestrial communication routes) and we analyse and compare their characteristics and functionality.

To assess properly the efficiency and the functionality of the infrastructural systems of fluvial and terrestrial routes in southern Etruria and Latium vetus specific efficiency measures have been calculated. The topology of a network is closely related to its functionality: from the brain to the Internet, from trophic relations to metabolic networks, the way all these systems work is closely related to the organisation of the connections. Terrestrial transportation infrastructures are no exception. They enable interactions between sites, a process that ultimately comes down to some sort of transfer (information, goods, etc.) among sites across a geographic space. Building from this idea, in the past fifteen years, different measures related to the

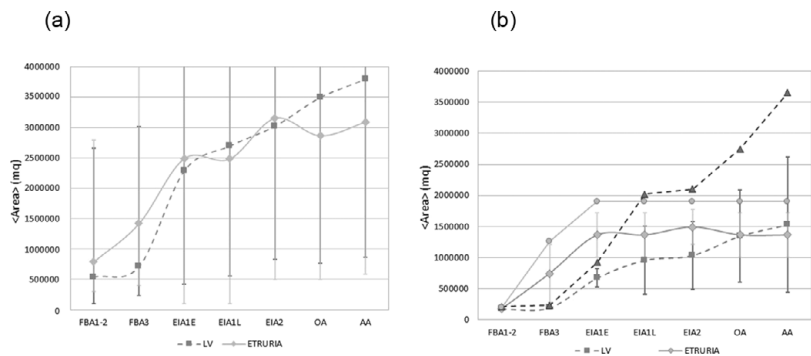


FIGURE 5.1. Trend of the median of settlement size in southern Etruria and Latium vetus: (a) Median of the first 50 settlements; (b) Median of the first 5 bigger settlements and of the biggest settlement. The bars indicate standard deviations.

concept of efficiency of communication in networks embedded in a physical space have been introduced.¹

In all these measures, weighting has been introduced based on the linear distance between sites. In this way, it has been possible to take into consideration the effort encountered to move from one node to the other and to introduce a simple but effective proxy to account for the morphology of the region. The two areas, in fact, are geographically similar and rather homogeneous and therefore a linear distance is sufficient approximation for the physical variability of the environment.² Both measures at the global and the local level have been considered. The first measure that has been considered at the global level is the global efficiency. This quantifies how well information is exchanged across the whole network, by assuming that the closer two sites are, the easier it is to transfer information between them.

In its simplest definition, the efficiency of the communication between two sites is calculated as the inverse of the shortest path length – that is the minimum number of links – separating them,³ divided by the linear distance between their locations. The longer the path between two nodes in comparison with their distance, the less efficient is the network. The global efficiency is calculated as an average on all pairs of nodes.

To assess the possible existing alternatives to the best optimal available route, the smallest positive value of the eigenvalue of the weighted Laplacian matrix or algebraic connectivity (Lw) has been calculated. This measure evaluates quantitatively the resilience of the infrastructure system at the global level. For further details and a mathematical explanation, we refer directly to Piet van Mieghem.⁴

At the local level, two other measures have been considered. Firstly, the average strength has been considered. In fact, to assess the overall connectivity of the system, the spatial nature of the transportation network requires us not only to consider the number of connections but also their length. The strength $\langle s \rangle$ extends the idea of node degree (number of connections) to the weighted case. Given a node i , $s(i)$ measures the total length of its adjacent links. The average $\langle s \rangle$ calculates then the average over the set of nodes. Given a node i , s_i measures the total length of its adjacent links.⁵

Secondly, the local efficiency of a node was proposed to quantify how well information is exchanged between its neighbours when that element is removed. This estimates how resilient a network is against localised failures. For example, if suddenly one of the nodes is not accessible anymore, what is the capacity of the neighbouring nodes to function and allow communication within the corrupted system? We adopted the definition from Vragović and colleagues,⁶ devised specifically for geographic networks.

As will be discussed in the following section, by adopting these measures we were able to characterise the connectivity of the Etruscan and Latin system, both at the local and global level, and compare them objectively in order to understand if their starting point was after all so similar and/or if there were differences in their infrastructural systems that might explain the very different outcome of the two regions.

5.2 Discussion of the Analyses and Results

Global Efficiency

When considering the global efficiency (Fig. 5.2), that is the capability of information/goods to flow between the nodes of the system through the best possible route, southern Etruria and Latium vetus show similar trends and similar values for the terrestrial routes network but different trends and different values for the fluvial routes network. The terrestrial routes networks values are higher than those of the fluvial routes networks and stay almost the same for all time slices in both regions. The fluvial routes networks values are generally higher for Latium vetus. In addition, the trend is slightly decreasing for the fluvial networks of Latium vetus, while it is fluctuating but almost steady for Etruria. A higher global efficiency within the terrestrial routes network within each region is not surprising because this type of network is much more flexible and adaptable than a fluvial network, which probably

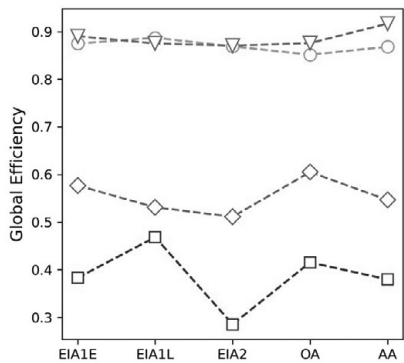


FIGURE 5.2. Global efficiency calculated on fluvial and terrestrial routes networks in southern Etruria and Latium vetus. Terrestrial routes Latium vetus = circles; terrestrial routes Etruria = triangles; fluvial routes Latium vetus = diamond; fluvial routes Etruria = squares.

would score a higher value at a supra/inter-regional level. The small decline in efficiency of the fluvial Latin network might indicate again that later, newly founded settlements, might have been located at key locations for terrestrial rather than fluvial route communication, given the fact that the fluvial network should be rather static by its own nature.

In contrast with the global efficiency, the smallest positive value of the eigenvalue of the weighted Laplacian matrix or algebraic connectivity (Fig. 5.3), which indicates the resilience of the global system to changes/crisis, shows very similar trends in southern Etruria and Latium vetus for the fluvial networks and very distinctive trends for the terrestrial routes networks. In particular, the smallest positive value of the eigenvalue of the weighted Laplacian matrix or algebraic connectivity has very low and steady values through all the periods from the Final Bronze Age to the Archaic Period for the fluvial networks in both regions. For the terrestrial route networks, in contrast, the smallest positive value of the eigenvalue of the weighted Laplacian matrix or algebraic connectivity has a clearly increasing trend for Latium vetus and an opposite dramatically decreasing trend for southern Etruria. This seems to indicate a clear infrastructural advantage of the Latin region over the Etruscan region.

Local Efficiency

At the local level, the calculation of the local efficiency, which indicates the capacity of the system to face a crisis at the local level (Fig. 5.4) shows

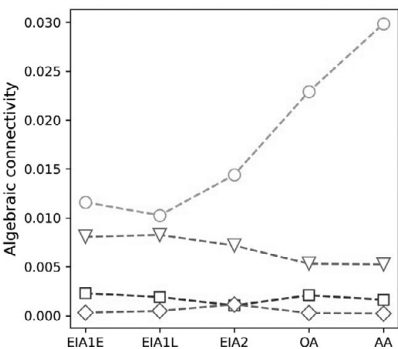


FIGURE 5.3. Smallest positive value of the eigenvalue of the weighted Laplacian matrix or algebraic connectivity (L_w) calculated on fluvial and terrestrial routes networks in southern Etruria and Latium vetus. Terrestrial routes Latium vetus = circles; terrestrial routes Etruria = triangles; fluvial routes Latium vetus = diamond; fluvial routes Etruria = squares.

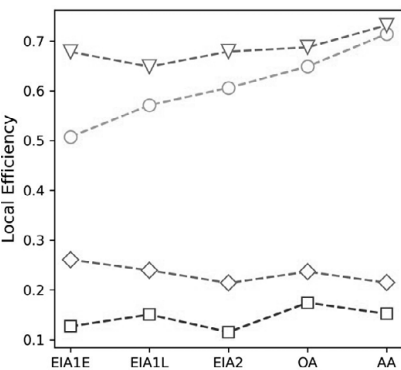


FIGURE 5.4. Local efficiency calculated on the fluvial and terrestrial routes networks in southern Etruria and Latium vetus. Terrestrial routes Latium vetus = circles; terrestrial routes Etruria = triangles; fluvial routes Latium vetus = diamond; fluvial routes Etruria = squares.

similar trends in southern Etruria and Latium vetus, both for the fluvial and the terrestrial routes networks. The values of the local efficiency for the fluvial networks are smaller than the values of the local efficiency for the terrestrial routes network, both in Etruria and Latium vetus. The trends of the terrestrial routes network are slightly increasing in both regions, while the trends of the fluvial networks are slightly decreasing. The values are generally higher in Latium vetus than in Etruria. This result seems to be consistent with the others. The terrestrial network system by its own nature

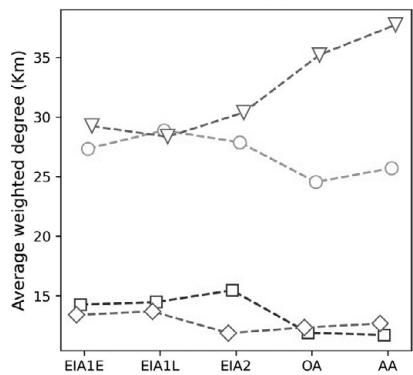


FIGURE 5.5. Average strength (or weighted degree) calculated on the fluvial and terrestrial routes networks in southern Etruria and Latium vetus. Terrestrial routes Latium vetus = circles; terrestrial routes Etruria = triangles; fluvial routes Latium vetus = diamond; fluvial routes Etruria = squares.

is more flexible and seems to improve through time, which means that probably new settlements are located at strategic positions to facilitate the movement across the region.

The other measure considered at the local level is the average strength or weighted degree, which indicates the mean of kilometres of connections available to each node-site. As well as the smallest positive value of the eigenvalue of the weighted Laplacian matrix or algebraic connectivity, this measure shows similar trends in southern Etruria and Latium vetus for the fluvial networks and different trends for the terrestrial route networks. The values of the fluvial communication routes are lower than the terrestrial communication routes, nearly identical for the two regions and almost steady through time. The values of the terrestrial routes network are similar in Etruria and Latium vetus for the Early Iron Age and increase for Latium vetus during the Orientalising and Archaic Period and decrease in Etruria in the same period (Fig. 5.5). This measure also seems to indicate a small advantage for the Latin region over Etruria.

5.3 Conclusions

The analysis of efficiency measures calculated on the terrestrial and fluvial networks of southern Etruria and Latium vetus provides not univocal but slightly variable results. At the global level, the global efficiency calculated on fluvial route networks shows a clear advantage of the Latin region over the southern Etruscan region, while the terrestrial route networks show

only a minor advantage. Contrastingly, the smallest positive value of the eigenvalue of the weighted Laplacian matrix or algebraic connectivity shows a distinctive advantage and a growing trend for the networks of the terrestrial routes in Latium vetus compared to Etruria, which has lower values and a decreasing trend, and only a small advantage for the fluvial connections. At the local level, the local efficiency seems to be higher for the terrestrial routes than the fluvial routes and the Latin systems seems to be more resilient than the Etruscan system in both cases, although the advantage decreases with older periods. To conclude, the efficiency indexes calculated on the fluvial routes of southern Etruria and Latium vetus provide similar results in both regions but indicate that the system in Latium vetus is slightly more flexible and efficient. The network of terrestrial routes, instead, shows different results for different indexes. While it seems that the overall design of the network is (almost) optimal in both regions (there exists a short route connecting each pair of sites), the total number of connections is larger in Latium vetus than in Etruria. Consequently, the resilience of the latter system to a local crisis (local efficiency) is slightly smaller, and there are not so many alternative paths if the best option (shortest path) is not available (lack of redundancy). This might contribute to explaining while a smaller but more compact and connected region such as Latium vetus in the end prevailed over a larger but less efficient Etruria.

CHAPTER 6

Multi-scale Analysis Based on Least-Cost Paths

6.1 Methodology

In the first stages of this research, presented Chapter 5, we consciously decided to not undertake least-cost-path analyses because we were interested in exploratory and experimental applications of network science approaches, and we were aware of several issues raised in the application of least-cost-path analysis. Therefore the trade-off between costs and benefits of such an application did not seem remunerative enough or worthwhile in the first instance. However, it was also clear from the analyses that the variable of distance was relevant for the analyses and that an integration of network science approaches within GIS applications, now more and more common, is promising and profitable.¹ Therefore, this chapter presents a multi-scale analysis of transportation routes in Etruria and Latium vetus based on least-cost path analyses, although we are aware of the critique and problems of such applications.²

Least-cost-path models that are very much dependant on the cost-surface are used in the model. Here adopted an equation originally developed by Tyler Bell, Andrew Wilson and Andrew Wickham to model the tracks of the Samnites within the Sangro Valley Project³ and then re-used and enhanced by Miriam Rothenberg to study mobility and connectivity within the re-evaluation of the Tiber Valley Project.⁴ As noted by Rothenberg:

Bell et al. chose to focus on slope, which has clear effects on terrain difficulty, stays fairly constant through time, and is easily measurable. They used a more complicated formula for creating their paths than did other studies, as they incorporated both a nonlinear relationship between slope and cost and considered the direction of movement across slopes (anisotropy). This accounted for how steeper slopes are disproportionately

more difficult to traverse than flatter ones and how ascending generally requires more effort than descending.⁵

The formula developed by Bell et al. is the following:

- $\text{cost} = \tan(\theta)/\tan(1^\circ)$

in which the tangent of the degree of slope is divided by the tangent of one degree steeper slopes approaching infinite cost, where θ represents the degree of slope.

While the field of study has progressed, and many more cost-surface formulae have been proposed, Rothenberg suggest that this one has been specifically developed for central Italy, has been adopted and quoted several times in subsequent works, and is relatively simple in its formula and parameters. Therefore, following Rothenberg, we also choose it for its comparability, suitability for the research area and its simplicity and straightforwardness.

6.2 Discussion of the Analyses and Results

Local Scale: The Tiber Valley Project Survey Data

The case study uses local scale data extracted from the Tiber Valley Project database, based largely on a full reassessment of the material collected by John Ward-Perkins' South Etruria Survey, and the results of which are being published in an edited volume⁶ plus online archive.⁷ Here, we use least-cost path modelling to assess routes between pairs of sites in each period (farms, high status sites and, in later periods, villas). The model used to create the least-cost paths at the local level was created by Rothenberg by using the ArcGIS function Model Builder and by using the Path Distance and Cost Distance tools (Fig. 6.1).

The modelled routes are then aggregated into networks and weighted for their frequency of use.⁸ The results show fragments of routes aggregating together into networks, with analysis repeated for each main period across the first millennium BC (Fig. 6.2). Finally, these routes are compared to known routes and roads, especially from the Roman period. These analyses showed that much of the Roman road network was already in use and even some of the long-distance consular routes, such as the Flaminia, were re-using some of the stretches primarily used for small local communications. Roman authorities may have formalised some of these routes, and created new connections, but many of the sections already existed. We can therefore think about the 'local' significance of Roman roads as much

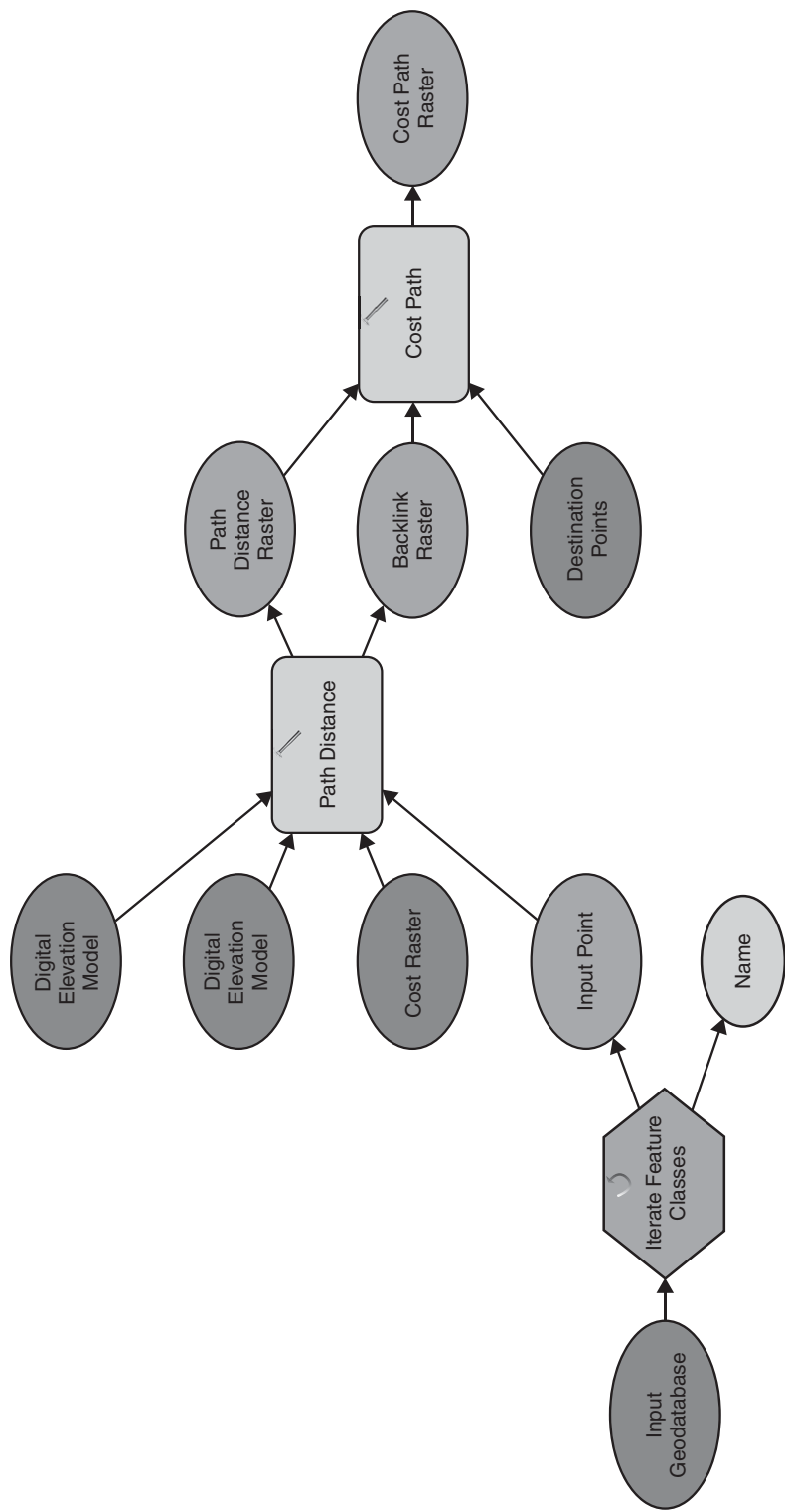


FIGURE 6.1. Flowchart showing input files (dark grey), tools (medium grey) and output files (light grey) of the cost path model (from Rothenberg 2014).

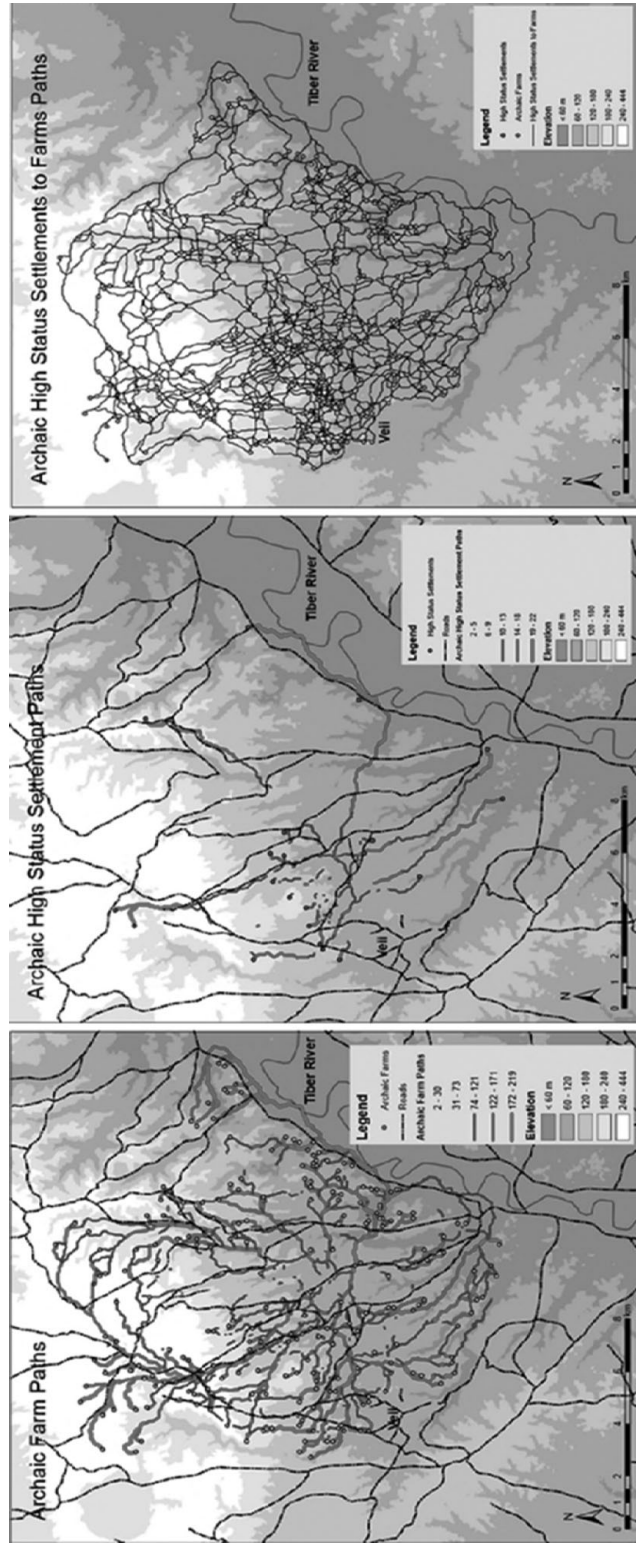


FIGURE 6.2. Tiber Valley Project: Archaic least-cost path routes compared with Roman roads. (From Rothenberg 2014)

the long-distance ones. Many of these sections were populated and were established ways of moving through the landscape.

Privileged routes between local centres may have become exposed to the dangers brought by passing armies. By the late republican and early imperial periods, being connected to this road network, with a large market at the city of Rome, would have brought opportunities (e.g. market production) and more local roads were constructed (or at least paved) helping to interconnect more areas with the network. These were locally developed, not state-imposed, and represent a new phase of local appropriation of the Roman network.⁹

The Regional Scale: Etruria and Latium vetus

At the regional scale we focus on both Etruria and Latium vetus. At this scale the least-cost paths routes have been created with the same cost-surface used at the local scale, but the networks have been modelled by using the cost-connectivity tool available in ArcGIS. The inputs of this analysis are a shape file of points/the sites and the cost-surface already presented before. One of the outputs of the analysis is an optimal neighbouring connection that connects the entirety of the region through the least cost-paths between all neighbouring sites not in linear distance but in cost of travel. Therefore, a site's closest neighbour is the cheapest one to travel to, not the one that is closest in distance. A cost-allocation operation, which uses the same cost-distance used at the local level, was performed to identify which sites are neighbours to one another. The second output of the cost-connectivity function is an optimum network created from the paths produced in the optimal neighbouring connections output. The paths in the optimal neighbouring connection output are converted to graph theory. The regions are the vertices, the paths are the edges and the accumulative costs are the weights for the edges. The minimum spanning tree is calculated from the graphical representation of the paths to determine the least-cost path network necessary to travel between the sites.¹⁰

The results of this analysis (Fig. 6.3) shows that relatively long inter-regional stretches of the Roman Via Aurelia, Via Clodia and the Via Cassia trace pre-existing routes connecting village to village through Etruria both in the Early Iron Age and even in the Bronze Age. Partially differently with the via Flaminia, some much shorter stretches appear to have been used, connected up to create a completely new route through Etruria that manages to bypass the main centres, but also giving a long-term boost to another otherwise unremarkable settlement at Oriculum, where the road

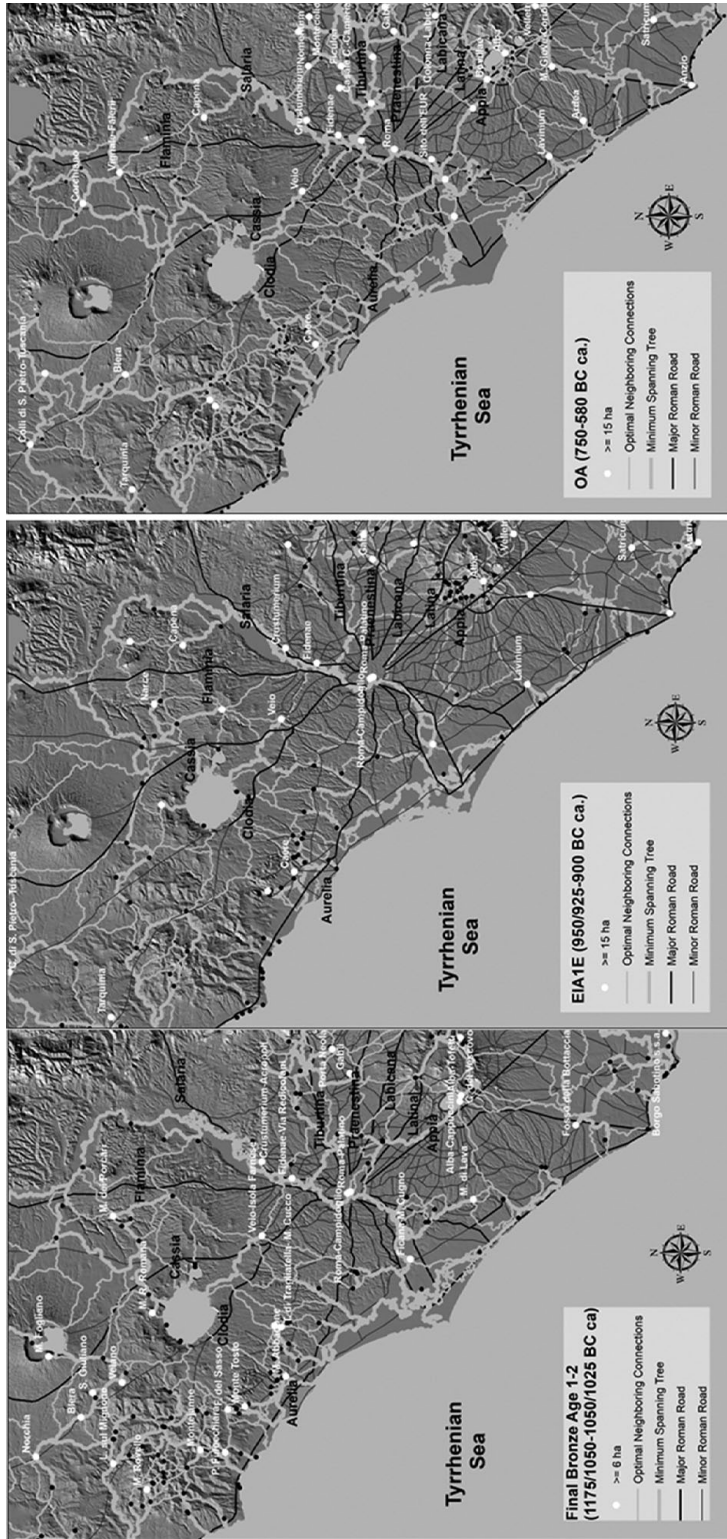


FIGURE 6.3. Etruria and Latium vetus: optimal neighbouring connections and optimum spanning tree compared with Roman roads. (By F. Fulminante)

crosses the Tiber. It is also interesting to note that the optimum network (thicker pale grey line) created by the function connects the larger and presumably more important settlements (white dots) in the region at the different times.

Beside cost-connectivity analysis also betweenness centrality has been calculated to show the potentially most used routes, respectively in the two regions Etruria and Latium considered separately. The combination of the two regions within the same system has not been performed yet and might yield different results. Etruria and Latium were neighbours and well-connected regions, and the Tiber often represented a permeable frontier and an occasion of encounter rather than boundary division.¹¹ However, during the Iron Age the two regions were very distinct political and ethnic units and therefore it seemed reasonable to consider them separately at least in the first step of the study. Betweenness centrality calculates how often a site is potentially crossed if an ideal traveller moves around the regional system in all possible directions from each site to all the others.¹² Therefore, as suggested already by Tymon Hass in his article on the economy and connectivity of republican Italy, the alignments of sites with highest betweenness centrality indicates also the potentially most used routes.¹³

This analysis (Fig. 6.4) seems to corroborate previous observations about the pre-existence of long stretches of the Via Aurelia, Via Clodia and Via Cassia, in the Orientalising and Iron Age if not in the Bronze Age. Partially the via Aurelia and more so the Via Clodia and Via Cassia,¹⁴ which follow important natural corridors and communications routes, respectively, along the coast, at the foot of the Apennine Mountains and over them, seem to have had potentially an important role in the communications within and outside the two regions, at least since the Orientalising and even earlier periods. To the south of the Tiber, in Latium vetus, the calculation of the settlements betweenness centrality seems to indicate that during the Final Bronze Age the most potentially important routes are located on the coast, between Roma and the Alban Hills and along the Aniene river valley, on the same route of the later Via Tiburtina; this analysis is coherent with the general archaeological interpretation of this historical period, when most abundant and significant evidence are found in those areas, near marine and fluvial resources.¹⁵

In contrast, in later periods, with the Iron Age and the Orientalising Age, other routes become more important, such as the east–west route, connecting Caere to Rome and then Gabii to reach further down in Campania and southern Italy through the Liri-Sacco Valley, and the north–south axes reaching the Alban Hills and the core of the region from the sea, through

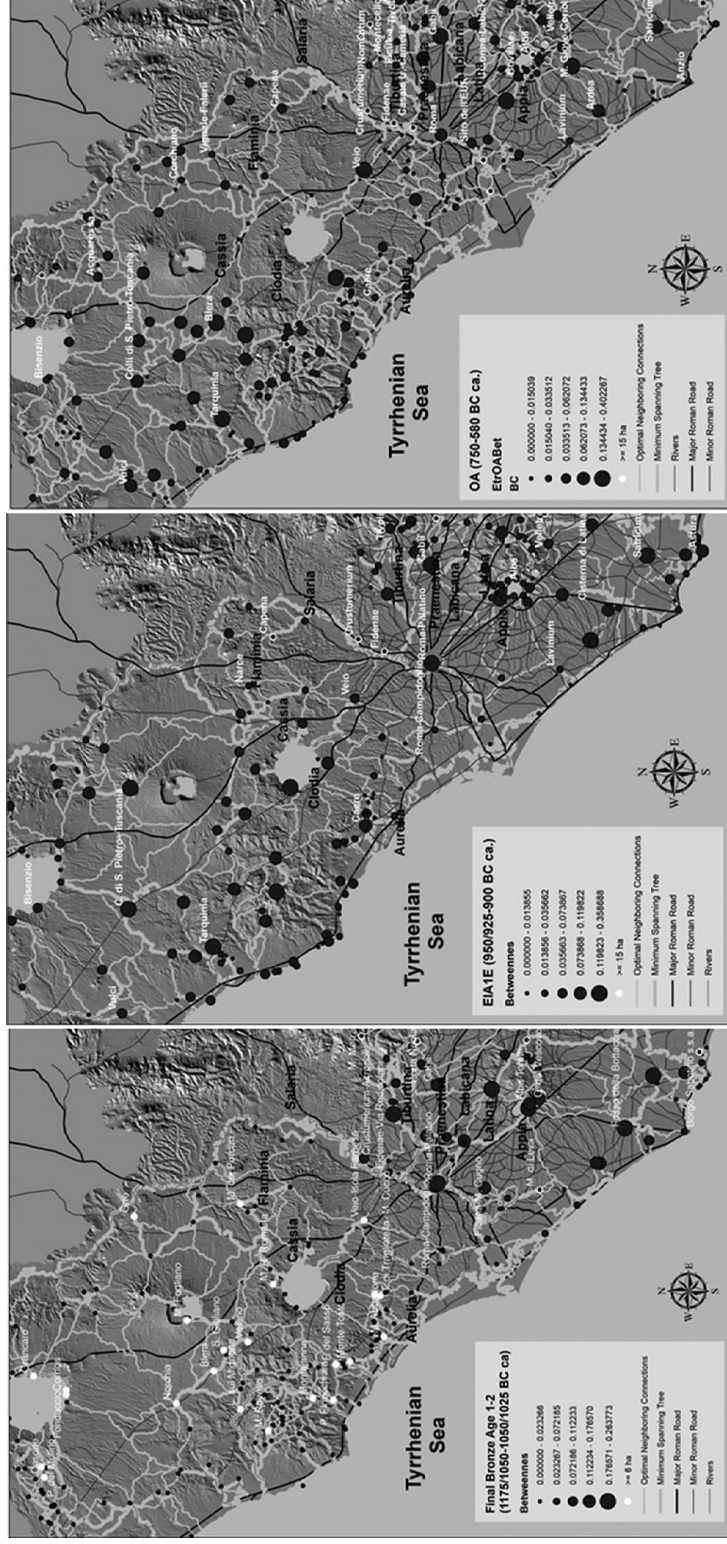


FIGURE 6.4. Etruria and Latium vetus: optimal neighbouring connections, optimum spanning tree and potentially most used routes (indicated by high scores of betweenness centrality) compared with Roman roads. (By F. Fulminante)

sites such as Ardea, Satricum and Cisterna di Latina.¹⁶ The importance of these routes seems to be confirmed also by another study I conducted on the distribution of imports in Latium vetus, which maps most of these objects, exactly along those routes.¹⁷

Settlement Scale: Rome and Veii

Previously, in her contribution on the origins of the Forum Romanum, Dunia Filippi emphasised the importance of this open area at the crossroad between the Salaria Vetus, which connected the salt production area near the estuary of the Tiber (*salinae*) to the internal mountain areas of central Italy and the Sacra via, connecting the Capitoline Hill to key areas on the Palatine Hills, such as the area of cult of Vesta and the residency of the Kings.¹⁸ This key position was enhanced by the presence of a ford, located between the Capitoline Hill, the Aventine Hill, the Palatine Hill and the Tiber, which a number of scholars have connected with the emporium (trading station) at the Ara Maxima, associated with the cult of Hercules and Cacus, both deities connected with salt and trade.¹⁹

Subsequently, in a more recent article, Amy Russell, fully developed the idea of the Forum Romanum as ‘a thoroughfare, a place of movement’, as opposed to the Imperial Fora, which ‘were largely not traversable’.²⁰ She was actually mainly thinking about local commercial and processional routes: ‘the Via Sacra paralleled the Palatine slope before climbing the Capitoline Hill and extended along the Forum’s long axis. Across the short axis ran the path from the river Tiber to the Esquiline heights, that is, from the river port and crossing at Tiber Island to Rome’s main residential area’.²¹

But she definitively had a point when she reminded us that ‘the Romans called this heavily traversed place in the city the *locus celeberrimus*, “the busiest spot,” and precisely because of its busyness, it became the most prestigious site for monuments’.²² According to Russell,

The Forum Romanum can be apprehended more as a monumentalized crossroads or even a widening of the Via Sacra rather than as an enclosed square. A great deal of traffic crossed the Forum on quotidian business in addition to the grand ritual processions that moved along the Via Sacra. A place to move through as well as a destination, its pre-eminence as a space of memory was largely determined by its relationship to the city’s movement patterns.²³

Combining Filippi’s observations with Russell’s vision and our own work on regional connections in Latium and Etruria, we like to think that

the Forum Romanum was also the crossroads of regional and interregional interactions as well as local movements and business. We know that since the reign of Augustus all roads were measured against the *Miliarum Aureum*, a monument possibly in marble and/or bronze and probably erected near the temple of Saturn in the Forum Romanum.²⁴ But due to modern urbanisation it is difficult to find actual traces of these routes, both in Roman and even more in pre-Roman times (although we know that they were most probably already in use²⁵), once they enter the Servian Walls.

However, a reconstruction by Tim Cornell of Rome at the end of the 4th century BC, in which evidence of roads in the centre of Rome is combined with morphological features of the terrain in the area, can give us an idea of potential movements and routes within and outside the city in previous times and clearly shows the Forum at the crossroads of important local, regional and interregional routes (Fig. 6.5). This perspective of fora as monumentalisation of previously used open spaces devoted to business and interactions, at the crossroads of intra-city and inter-cities networks is also confirmed by the consideration of the case study of Veii, where recent geophysical investigations have revealed the earliest features of the urban layout, monuments and routes with extreme accuracy and precision. As shown in Fig. 6.6, the geophysical investigation has allowed us to confirm the presence of a main route, most probably already in use in pre-? and protohistoric times, crossing the plateaux of Veii from northeast to southeast, connecting the northern part of southern Etruria to Veii and this city to Rome and Fidenae in Latium, whose importance had already been emphasised by Ward Perkins within the Tiber Valley Survey Project.²⁶

The recent geophysical investigation, however, has also allowed identification of a number of routes converging towards the middle of the plateaux, significantly near the area later occupied by the Forum Romanum. These routes align remarkably well with those potentially used in protohistoric times and identified through the collation of all information about current interpretations of various scholars working in the Etruscan region and the comparison with later known roads and alignments of pre- and protohistoric settlements. The hypothetical alignment of the routes, identified by geophysical investigation, on the plateaux of Veii, with the alignment of the reconstructed inter-regional routes has been possible only for the northern part of the plateaux (routes dotted in light grey); in the southern part reconstructed inter-regional routes have been indicated but have not been matched to geophysical evidence because the

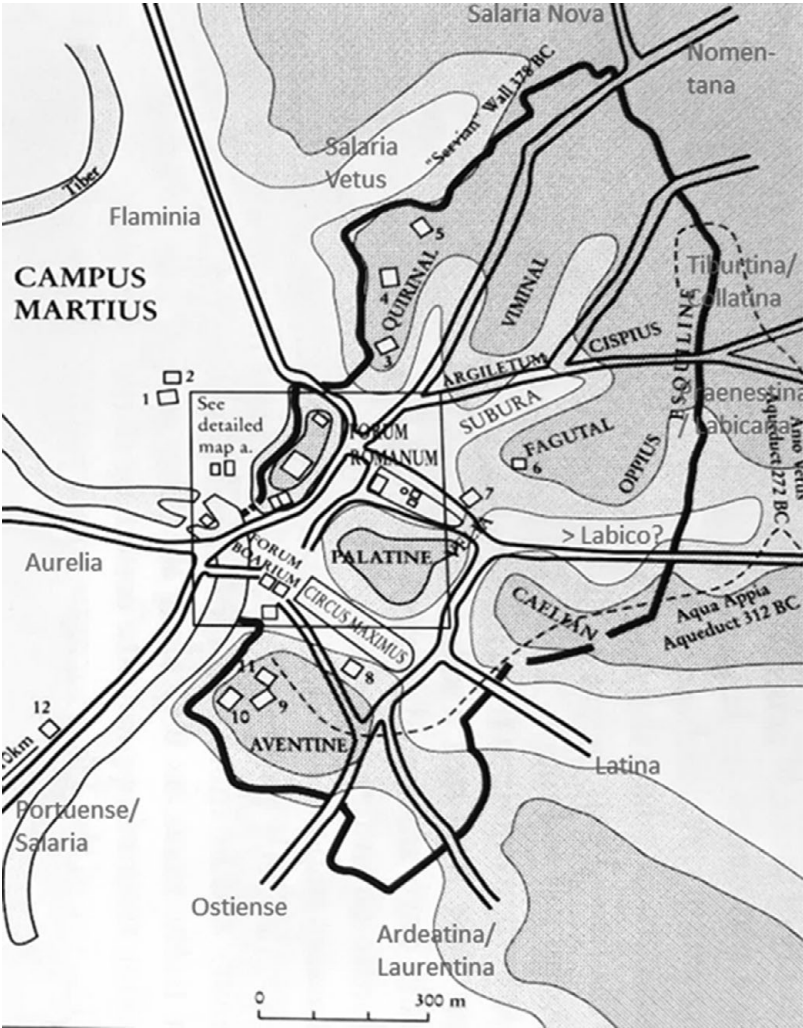


FIGURE 6.5. Rome at the end of the 4th century. (From Cornell 1995, map 10, p.386 modified by F. Fulminante).

exact alignment was more difficult to identify (routes dotted in dark grey). Another major route, of regional importance, crossing the plateaux of a city, has been found in Crustumerium, where it assumed a particularly monumental aspect in the deep and massive cut made to create it;²⁷ this would certainly have needed the mobilisation of a remarkable labour force for a sustained and prolonged period of time.²⁸

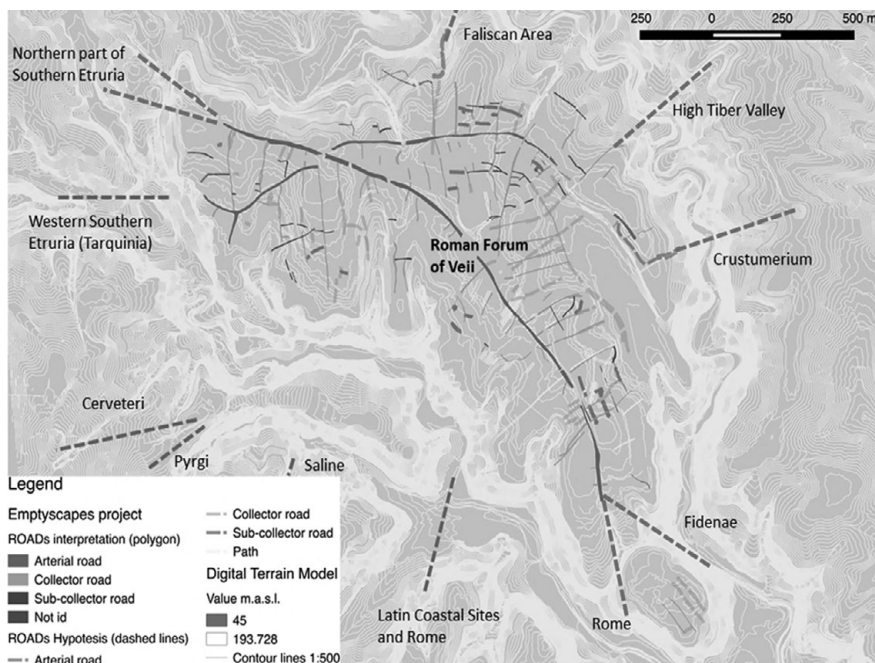


FIGURE 6.6. Veii in the Archaic period from the interpretation of the geophysical investigations by RL Campana. (Courtesy of the author modified by F. Fulminante)

The interpretation of fora as crossroads of regional and inter-regional connections, and the archaeological evidence within several settlements of monumental road-cutting for the realisation of these routes seems to confirm the importance of terrestrial transportation routes for the birth and development of Iron Age proto-urban settlements, which probably imposed taxes and pay-tolls on them, both in Etruria and Latium vetus, as already suggested by Francesco di Gennaro and demonstrated quantitatively above in Chapter 4.

6.3 Conclusions

Generally, Roman roads have been widely seen as state-imposed, coherently planned infrastructure system networks that transform regional geographies and impose new costumes and ways of life. Pre-Roman routes are seen developing on a more local scale, linking site to site, with no distant destination. They are emergent networks that developed by (some degree of) cooperation / communication between neighbouring communities.

This contrast is best expressed by Ward-Perkins who contrasted Etruscan road local network with the Italy-scale road network of the Roman period. Ward-Perkins recognised that Via Clodia moved village to village along old Etruscan routes, but: ‘The Via Flaminia, on the other hand, built in 220 BC, marks a complete break with tradition’,²⁹ even though he is clear that it incorporates parts of pre-existing routes (as did the Via Cassia). This is because he is focused on the new purpose of the roads: ‘it was laid out quite without regard for the existing pattern of settlement, with the sole purpose of providing a quick and easy route to the north. Its objectives lay far beyond, and although it incorporated stretches of existing road, this was purely incidental to its main purpose’.³⁰

One of the key issues to maintain here is the shift in scale from Iron Age regional political and ethnic units to the geographical and political unity of Roman Italy, which seems to retain prominence and importance in the development and dynamics of expanding communication network systems. However, the geographical unity of the peninsula was there even before the Romans and the material culture of Bronze and Iron Age Italy testifies to intense and far reaching connections across the whole peninsula, within a generally homogenous culture during the Bronze Age (Apennine culture)³¹ and more regionally defined cultural groups emerging during the Early Iron Age,³² but possibly preceded by regional local trading networks that favoured the subsequent emergence of political units.³³

As shown by Tesse Stek in a recent article on the expansion and colonisation of ancient Italy during the Republican Period, the Romans often incorporated and developed for their own advantage previously existing hubs and places of networking opportunities such as pre-Roman rural cult places.³⁴ This is mirrored by the case studies of Rome and Veii presented above, where it is possible to recognise the fora of the Roman Period as a monumentalisation of pre-existing open spaces at the crossroads of regional and inter-regional connections.

Basically, tracks existed before and were reused (or rather continued to be used) in Roman times, but sections were added (especially bridges) and pre-existing routes were formalised into a single *named* road. But apart from a new imposed coherence and some extra infrastructure, what changed? Places were already connected – goods were moving from one side of Italy to the other and from top to the bottom of the peninsula, far back into the Bronze Age – so perhaps it would be possible to see braids of routes narrowed down a single definitive road at the global/Italian scale. In further development of this work, we plan to look at how the ‘local’ routes of the pre-Roman period possibly aggregated into long-distance routes.

Clearly there is a difference between an engineered (and legally designated) road and a general route defined by usage, but with this pioneering work we want to better contextualise Roman roads by acknowledging/linking with their pre-Roman antecedents to emphasise their emergent properties. We also want to follow the development of these roads within the Roman period that allows for the evolving character of these networks to be explored. The ‘densification’ of the network from late Republican period / early imperial period probably represents a largely local transformation of state infrastructure (itself based on ‘traditional’ routes).³⁵

CHAPTER 7

Modelling

7.1 Methodology

Our purpose, in this chapter, is to infer how settlements were organised at the regional level by analysing the structure formed by the roads that connected them. The basic idea is to compare different hypotheses and quantitatively assess which of them is (or are) more plausible and, we do this in three steps (see Section 3.2). Adopting a network science approach implies that the first step is to translate available information on pathways from the usual map format into networks, that is, mathematical structures made up of interconnected objects. Once the empirical system is mapped onto weighted geographical networks, one can apply the established analytic tools provided by network science for their characterisation.

However, such a methodology cannot consist of a mere analysis of network properties. We need to link the observed properties to the mechanisms that generated them. The final output of the application of the proposed technique is statements of the type ‘since we made an observation X , then process Y is more likely to have occurred than process Z ’. Therefore, the second step is to hypothesise generative mechanisms that might have created the empirical network and to contrast their different outcomes (synthetic networks) against the empirical evidence. More concretely, we devise competing network models, each one corresponding to a strategy according to which the nodes made decisions about which links had to be established.

The third and last step is the validation of the proposed models. We test whether the synthetic networks that they generate are able to reproduce structural features of the empirical networks with satisfactory accuracy. If there exists at least synthetic network among them whose output resembles

closely enough the empirical observations, then we may conclude that its underlying mechanism shares some similarities with the actual processes that generated the terrestrial transportation under study. In the following subsections, we describe in more details each one of the methodological steps.

Characterisation of Terrestrial Route Networks

We are interested in characterising terrestrial transportation infrastructure systems by means of particular features that conditioned the way they functioned and determined their performance, that is, the efficiency and robustness of the communication that took place. Such systemic features are not defined by individual connections between specific pairs of settlements, but by the whole of them. For instance, we might overly focus on the presence of central places much better connected than many peripheral ones (inequality) or the existence of routes or settlements that if inaccessible made the network fall apart (fragility). Hence, we selected and calculated five network metrics that translate in quantitative terms some relevant features of the terrestrial transportation infrastructure system of Etruria and Latium vetus from the beginning of the Early Iron Age to the end of the Archaic Period. In other words, these indicators were chosen in such a way that two networks with similar values in all their measures are expected to perform similarly in terms of transportations and communication processes.¹

The selected network measures are: (1) average node strength (also known as average weighted degree) $\langle s_i \rangle$; (2) average edge length $\langle l \rangle$; (3) average clustering coefficient $\langle C \rangle$; (4) global efficiency $\langle E_{\text{glob}} \rangle$; (5) local efficiency $\langle E_{\text{loc}} \rangle$. These measures are explained in detail in a recent publication by the authors² and in Appendix B. The first three measures are common in network analysis and represent respectively: the mean total length of the links adjacent to a node; the mean of the weights (length) of all links present in the system; the presence of closed triangles in the network. The last two, however, are less common and specific to geographical network analysis.

In particular, as already anticipated in Chapter 5, the concept of **efficiency** can be applied to networks both at the **local** and **global scale**. The efficiency of communication between two sites is defined by the length of the shortest path (on the network) between them divided by the linear distance between their locations: the longer the path between two nodes in comparison with their distance, the less efficient the network. The

global efficiency is calculated as an average on all pairs of nodes. The local efficiency measures the capacity of the network to react to a crisis at the local level. More concretely, the local efficiency of a node defines how efficiently information is shared and moved among neighbours if that node is eliminated.³

Principles of Network Modelling

To get a better understanding of how settlements were organised at the regional level, we analyse the structures formed by the roads that connected them to try to unveil the mechanisms underlying the decision-making processes that created them. To this end, we produced models able to generate 'synthetic networks' from different hypothetical mechanisms and compared such networks with their empirical counterparts obtained as explained above, for each age and region.

The idea of network models as a means of explaining some features of real networked systems dates back to the late 1990s and builds up on a long tradition developed in the framework of mathematical sociology during previous decades. Initially, the three most-studied properties of social networks (and later on of other types of systems, such as citation networks, airport networks or the world wide web) have been: the degree distribution (how many nodes have how many links); the clustering coefficient; and the average path length (the average number of steps along the shortest paths for all possible pairs of network nodes). A large part of empirical networks have heterogeneous degree distribution, high clustering coefficient and very short path length (the famous 'six degree of separation'). Already in the 1970s, it was clear that this combination of features cannot be explained as the mere effect of chance, neither can they be obtained by building connections according to simple mathematical rules. For instance, if we connect node pairs at random with a certain probability, by tuning such probability, we are able to reproduce the observed number of links of any empirical system and the average path length is also likely to be close to the observed one. On the other hand, the degree distribution will be much more homogeneous and the clustering coefficient (related to number of triangles) significantly lower. Alternatively, it is straightforward to come up with a mathematical rule for connecting nodes such that the clustering coefficient is similar to the observed one, but then the average path length will be too large and the degree distribution still too homogeneous. Both random and regular networks reproduce some of the features of real networks, but they cannot display them all together. This is the main

motivation for the onset of network science: to answer the question of which mechanisms are able to generate the properties of real networks.⁴

Such mechanisms are implemented as algorithms that work in different fashions: in some cases, they take as a starting point a regular or random network and proceed to modify it by rewiring or adding connections; in other cases, nodes are also added at each step. One of the most paradigmatic network models is the Barabási-Albert (BA) model,⁵ an algorithm that adds nodes one at a time. Each new node establishes a connection with any of the existing ones with a probability proportional to the links that the latter already has. In other words, the new nodes have a ‘preference’ to attach themselves to the already heavily linked nodes. Thus, heavily linked nodes (‘hubs’) tend to quickly accumulate even more links, while those with only a few links are unlikely to be chosen as the destination for a new link. The BA algorithm simulates a system that experiences the well-known ‘the rich get richer’ effect, and the resulting synthetic networks display a highly heterogeneous degree distribution. In more concrete terms, we can imagine that each node is, for instance, a scholarly paper, while the links stand for citations. Although the actual criteria for selecting references are far more complicated than the mechanism implemented by the model – no one picks papers at random according to a certain probability – the BA algorithm captures a general trend (highly cited papers are more likely to be cited even more) and is able to reproduce a distinctive feature of real citation networks. In this way, the hypothesis that authors when building a list of references for a new publication tend to have a preference towards already popular papers, can be corroborated (even though it is not definitively proven, since it is still possible that another model implementing a different mechanism could reproduce the same trait). Citation networks are not the only type of system that can be (partially) explained by the BA algorithm, which was originally devised as a network model for the Web. Its importance does not lie in its ability to perfectly reproduce some phenomena but in the capability of capturing something general that is common to a wide range of systems. The same algorithm can be interpreted in many ways according to different contexts (nodes may be papers, websites, airports, hence links are citation, hyperlinks, flights, etc.), while the underlying mechanism stays unchanged. This is, roughly speaking, how network modelling works: an abstract mechanism (e.g. the rich get richer) is translated into a generative algorithm for networks (e.g. preferential attachment), but in order for the model to explain something specific about the system under study, we need an interpretative metaphor (e.g. highly cited papers have greater visibility).

Network Models for Terrestrial Transportation Infrastructure Systems

In our work, each network model implements an algorithm that, starting from a certain number of disconnected sites (the settlements of the empirical networks), decides what links should be added to build up the artificial networks. The approach is similar to BA's, but in this case the nodes, instead of being characterised by the timestamp of their creation, are characterised by their geographical coordinates. They all exist in the initial state, while the links are created one at a time.

Since our goal was to unveil the basic principles governing the interaction between the different communities of a regional system, we had to consider a limited number of radically dissimilar scenarios. In the first, settlements did not have information about the terrestrial transportation infrastructure at the regional scale, neither did they share any common interest; in the second, they did have information at the regional scale, but shared no common interest; in the third and last, they had both regional scale information and common interests. In all these cases, we made the general assumption that any settlement needed to be well connected, that is, they all actively tried to get as many links as possible. More specifically, we assumed that each settlement pursued being able to reach any other through as short a path as possible. What differs in the three scenarios is their means and criteria for setting priorities.

Once the basic assumptions were set, we proceeded to translate them into algorithms for establishing links between nodes. This step implies a certain degree of lack of determination since it can be performed in multiple ways. Simplicity was the guiding principle that shaped our models. Refinements are always possible afterwards, but the baseline needs to be directly connected with the main concept one wants to test. Otherwise the interpretation of the result becomes more difficult and potentially ambiguous. Hence, we designed a minimalistic set up in which each node, at each step, had a preference about which link had to be built, and it was always a link connecting itself to another node which it considered to be the most beneficial for its connectivity. Such individual (local) preferences were sorted in different ways, depending on whether the settlements were interested in building a functional terrestrial transportation infrastructure at the regional scale (third scenario) or not (first and second scenarios). If they were interested only in their own connectivity, every settlement wanted its preferred link to be established at the next step; otherwise, they tried to reach some kind of agreement and their preferences were sorted according to a shared

criterion. On the other hand, the way they set their preferences depends on the information available to them.

After defining the abstract principles, we needed to translate them in terms of rules for establishing links, thus devising a set of generative network models. For the sake of simplicity, we made the additional assumption that all node-settlements were intrinsically equally important. In other words, we did not make any supposition about their power, richness or attractiveness: Our models take as an input no other node attributes beside the geographical position. In this way, the node-settlements based their choice on geographical (distances) and topological (already existing links) information only. In the first scenario, their knowledge was limited to the links that connected them to other nodes, while in the second and third scenarios, nodes knew any existing path joining them to any other place independently on the number of steps (intermediate nodes). Hence, in the first case, at each step, each node's preference was to build a new link with the closest node that was not already connected to it. On the contrary, in the case they had complete topological information (second and third scenarios), since their goal was to improve their connectivity, they would have preferred to compare the length of any existing path connecting them to any other node with the length of the corresponding direct link, to better assess the benefit of building it. In quantitative terms, the most beneficial link would be the one that minimises the ratio of its length to the length of the shortest existing path to the same node (best shortcut).

Finally, we implemented the interplay between the individual node-settlement interests. If it was pure competition, then at each step every node tried to prevail over the rest and build its preferred link. A realistic simulation of such processes, besides being extremely difficult, would have not fitted in with the minimalistic approach of network modelling. More importantly, it was not necessary. We took a step back and assumed that the output of the competitive interactions between node-settlements was indeterminate. Each node had the chance to prevail at each step, according to a certain probability distribution, but we did not know a priori which one was going to build a new link at the next step. Therefore, the corresponding network models (first and second scenarios) were not deterministic. If we ran them several times, they generated several different networks – similar to what happens with the BA model – and their outputs had to be analysed statistically. To avoid making arbitrary assumptions, at this stage, we decided that the probability distribution had to be uniform, that is, each node had the same chance to prevail at each step.

The third scenario presents a radically different situation. Since in this case the nodes were supposed to reach an agreement and decide collectively which link had to be built at each step, we had to set a criterion for doing so. They would have compared their individual preferences and set for the most beneficial at the regional scale. This process could have been easily implemented as the optimisation of some function and there were various plausible options that we could have adopted. Once more, seeking simplicity, we chose not to introduce a new ingredient. Individual preferences were already set according to a quantitative criterion and that same criterion could be exploited to compare them. Thus, at each step, the model built the shortcut that was the most beneficial of all, shortening paths at the regional scale.

Summarising, in the first model, called the L-L (local-local) model, node-settlements pursued their local interests relying, for their decision making, on local information. At each step, a node was extracted at random and a new link was built, connecting it to the closest one among the nodes not already connected to it. The second model, which we named the G-L (global-local) model, shared with the L-L model the fact that node-settlements pursued their local interests, but they did so basing their preferences on global (system-scale) topological and geographical information. At each step, a node was extracted at random and, among all the possible links connecting it to any other node, the one that minimised the ratio of its length to the length of the already existing shortest path will be established. Both the L-L and the G-L models are not deterministic and each run produces, in principle, a different network. In the third and last baseline model, the nodes had global information as in the G-L model, but pursued a regional-scale benefit, mediating between their local preferences. At each step, the algorithm built the link associated with the (globally) minimal value of the ratio of the geodesic distance between two disconnected nodes to the length of the already existing shortest path joining them. This model is deterministic and will always generate the same network for a given set of input parameters. We named it the equitable efficiency (EE) model because of the effect of the algorithm on the global efficiency of the networks that it generates. As an illustrative example of the kind of connection patterns generated by the three models, in Fig. 7.1 we represented the empirical network of Early Iron Age 1 Late (EIA1L) with its artificial counterparts: one realisation of models L-L and G-L and the output of the EE model.

Besides the three baseline models, we devised a fourth by introducing a simple modification to the EE model, thus including a version of

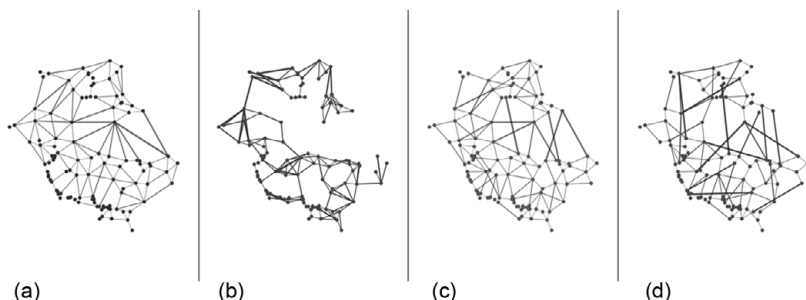


FIGURE 7.1. Example of network realisations: Networks of EIAI.L. (a) Empirical; (b) Random characteristic realisation of model L-L; (c) Random characteristic realisation of model G-L; (d) model EE.

‘preferential attachment’ (model EE-pa) that, in this case, was integrated in the framework of a deterministic algorithm. Without entering into technical details, the main idea was that, while in the original model all the settlements were on the same ground and the links to be built were selected among the individual preferences according to an objective and fair criterion, in the modified version the preference of nodes with more and larger links were entitled to a higher priority level. In this way, nodes with greater strength (total length of its adjacent links) tended to gather even more.

To complete the definition of the models, there was one more rule that needed to be set. It was necessary to establish a stopping condition for the creation of new links. Since the aim was to compare the networks generated by the models with the empirical ones, we considered that it was appropriate to equate their total link length. The algorithms take as input the positions of the settlements and build links between them until the total length of the connections that have been established is equal to that of all the connections in the corresponding empirical network⁶).

7.2 Discussion of the Analyses and Results

Assessment of the Network Models

To assess whether any of the proposed generative mechanisms were likely to have shaped the southern Etruria and Latium vetus terrestrial transportation infrastructure system, we compared model generated networks with their empirical counterparts, for each age and region. We performed such comparisons considering the network metrics that we proposed for the characterisation of terrestrial route networks (see Section 7.1). Here, we summarised the most relevant results, while a technical

discussion of quantitative aspects can be found in previous works⁷ and in Appendix B.

Concerning southern Etruria, the first two models captured some of the characteristics of the empirical networks but missed some others. Specifically, the **L–L model** overestimated the clustering coefficient and the local efficiency and underestimated the average edge length and the global efficiency. On the other hand, the **G–L model** underestimated the clustering coefficient and overestimated the average edge length but is an almost perfect match for the global efficiency. In contrast, the **EE model** reproduced with good accuracy all the relevant features of the empirical networks for all periods considered, with the only exception of a non-negligible difference in the clustering coefficient for the last three periods (Figs. 7.2 and 7.3).

Differently from Etruria, in Latium vetus each model reproduced some of the trends of the figures of the empirical networks but always missed some others. In particular, the **L–L model** did not reproduce any of the trends of the empirical network (except for the global efficiency in two particular periods, namely Early Iron Age 2 (EIA2) and Orientalising Age (OA)). The **G–L model** reproduced quite well the average edge length, the local and global efficiency, but underestimated the clustering coefficient. Model **EE** reproduced quite well the clustering coefficient and the global efficiency (similar to the G–L model) but underestimated the average edge length and overestimated the local efficiency (Figs. 7.4 and 7.5).

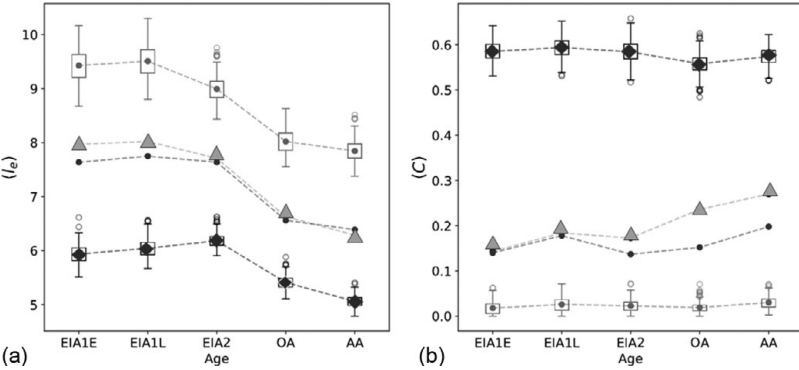


FIGURE 7.2. Values of $\langle l_e \rangle$ (a) and $\langle C \rangle$ (b) for the empirical and synthetic networks of southern Etruria: empirical network grey triangles, model L–L black diamonds, model G–L grey dots, model EE black dots. Points stand for average values, boxes span from the lower to the upper quartile values, and whiskers show the range of data.

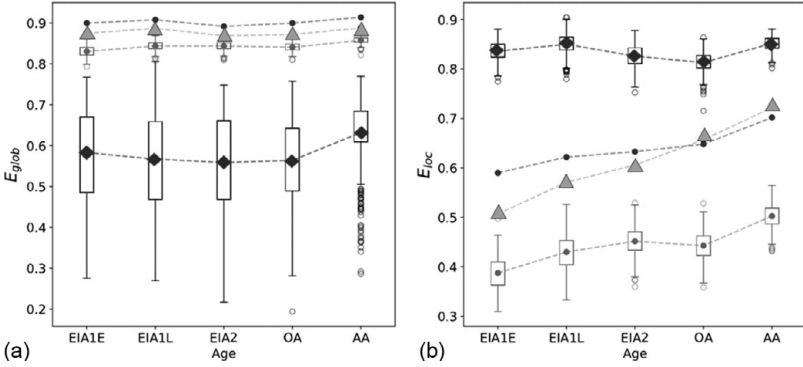


FIGURE 7.3. Values of E_{glob} and E_{loc} for the empirical and synthetic networks. See Fig. 7.2 for more details.

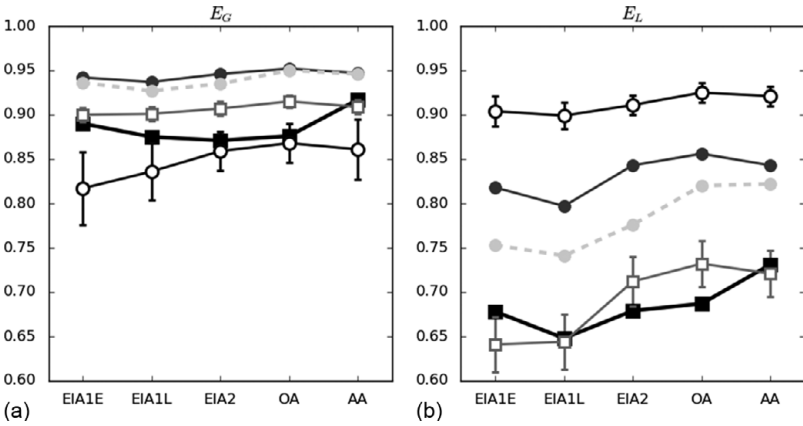


FIGURE 7.4. Average edge length ($\langle L \rangle$) (a) and average clustering coefficient ($\langle C \rangle$) (b). Key: empirical network (black filled squares); averaged output of model L-L (black open circles); averaged output of model G-L (grey open squares); output of model EE (black filled circles); averaged output of model EE-pa (light grey filled circles and dashed line).

Furthermore, in the empirical networks, the heterogeneity of the node strength (measured as its standard deviation, Fig. 7.6) was greater than in any model generated counterpart. Adding a tunable preferential attachment mechanism to the EE model (model EE-pa) enabled us to generate topologies that resembled the empirical ones more accurately, although not as accurately as the EE model did in the case of southern Etruria (Figs. 7.4 and 7.5).

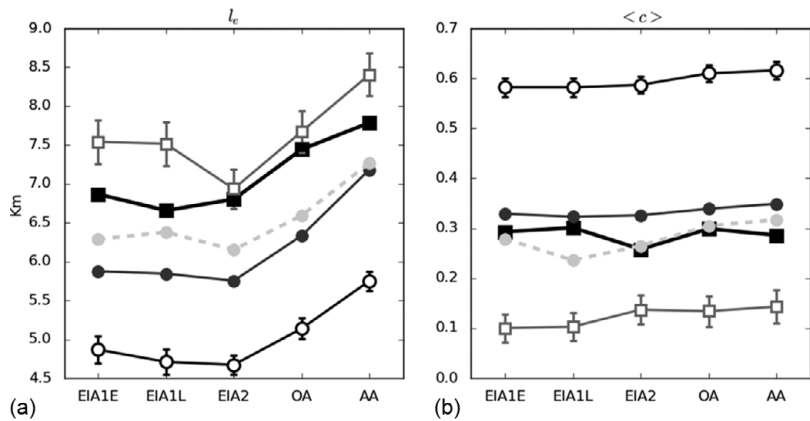


FIGURE 7.5. Global efficiency (E_{glob}) (a) and local efficiency (E_{loc}) (b). Key: empirical network (black filled squares); averaged output of model L-L (black open circles); averaged output of model G-L (grey open squares); output of model EE (black filled circles); averaged output of model EE-pa (light grey filled circles and dashed line).

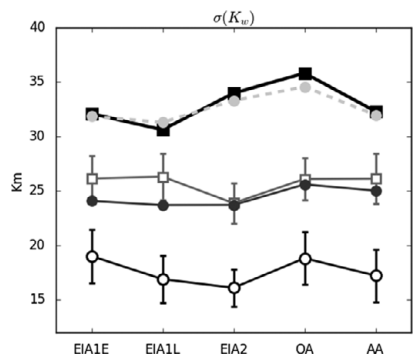


FIGURE 7.6. Standard deviation of the weighted degree of nodes. Key: empirical network (black filled squares); averaged output of model L-L (black open circles); averaged output of model G-L (grey open squares); output of model EE (black filled circles); averaged output of model EE-pa (light filled circles and dashed line).

Interpretation of the Quantitative Results

The proposed network science approach allowed us to hypothesise basic mechanisms that could have governed the decision-making process that shaped the terrestrial route network of the two regions under study. Our conclusion is that, likely, all the actors involved (cities and villages) were trying to build terrestrial transportation systems such that it was possible to

reach every place from any place through a fairly short path and not permitting the existence of poorly connected areas, which could have damaged the functioning of the settlement system (in terms of commerce, communication and defence) at the regional scale. It is interesting to note that in a least-cost path network classification proposed by Waugh,⁸ this type of network, defined as 'least-cost-path to the builder', is typical of agrarian societies, where arable land is precious, or scarcely populated regions, where creating routes is too expensive. This type of network contrasts with the so called 'network to the user', which connects in the quickest way each possible pair of the system and is typical of hunter-gatherer societies.⁹ Both Latium and Etruria are definitively agrarian societies growing in complexity, and Etruria is probably slightly less densely populated than Latium. A third type of network, compromising a middle way between the two above, is the 'least cost triangulation network', in which the least-cost is applied only to nearest sites, implying that connections to close sites are more important than distant ones. Interestingly, we applied the Delaunay model triangulation to build Latin networks in an earlier work, and they performed rather well in term of connection between centrality indexes and centres predicted to be important by their size.¹⁰ A drawback of all these models is that they assume equal rank and contemporaneous sites. We will go back to these classifications in further work on least-cost paths networks.

However, it is important here to note that while in southern Etruria this seemed to be the only preoccupation of all the cities and villages, regardless of their status, in Latium vetus those that had been initially favoured by their location, appeared to exploit such condition pursuing local ambitions for even better connectivity. Nonetheless, this distinguishing element did not excessively disrupt the balance at the regional scale. Latium vetus still had a very efficient terrestrial transportation infrastructure, despite few sites being characterised by a greater number of connections. The Latins could probably afford to build a more heterogeneous (less equitable) terrestrial transportation infrastructure system, thanks to the relatively large total link length of their network, which allowed them to limit the damage of a non-optimal geographical distribution of paths. It is indeed worth noticing that, even though the total link length is generally larger in southern Etruria than Latium vetus, if properly compared – taking into account the number of nodes and their average distance¹¹ – the latter turns out to be considerably better connected. Consequently, implementing a rich-get-richer mechanism would have been critical for the Etruscans. We cannot say whether the equitable nature of the interactions between Etruscan cities made their

resources scarcer (both in terms of settlement density and roads) or instead it was the other way around, disclosing this kind of causal relations is beyond the scope of our methodology. Nonetheless, our results suggest that a compact and highly connected region as Latium vetus could sustain unbalanced powers, while for southern Etruria – a bigger and less densely populated region – power balance looked almost as the only option.

At a closer inspection, we found hints that the introduction of preferential attachment as a refinement mechanism to the EE model, could explain the emergence of Rome as a prominent site (see Fig. 7.6). According to the EE-pa model, some sites, favoured by a convenient geographical position (in relation to the rest of the sites), were able (and willing) to leverage on this initial advantage to increase their influence and gather even more power. In the case of Rome, which had the greatest node strength in the empirical networks, the site happened to be also favoured by the algorithm. However, in the case of other heavily connected cities – such as Gabi – the model failed to explain their strength. At the same time, the algorithm bestowed greater strength to other sites, as for instance Satricum or the considerably less important site of Guadagnolo.¹²

The EE-pa model reproduced a specific feature presented by Latium vetus terrestrial transportation system that neither the G–L model nor EE model could reproduce, that is, the existence of few sites with many distant links (Fig. 7.6), but it was not supposed to correctly show who prevailed over whom. We did not expect such basic models to reproduce correctly the local scale since there were too many factors that could have determined what happened at the level of individual settlements, factors that were not included in the proposed algorithms. Nevertheless, the apparent emergence of Rome as the most important hub of model generated networks, hints at the crucial role played by its geographical position within the system of settlements, the only attribute that the algorithm takes as an input.

The case of southern Etruria was different: There was nothing particularly remarkable at the local scale. Not only was the empirical node strength distribution less skewed, but the network metric itself seemed also to be almost unrelated with the importance of the corresponding sites, that is, it show lower correlation with the settlements' size. In this case, the association between strength and power was weak, a fact that was consistent with the capacity of the EE model of reproducing the most important feature of the empirical network accurately assuming that all the nodes stood on the same ground (no preferential attachment), not considering which ones had been favoured by their position in the first steps of the

algorithms. That is, possible initial advantages in terms of connectivity did not represent, in southern Etruria, a source of power imbalance and, in general, being better connected did not imply being more important.

Synthetic Evaluation of the Results: Specificity of Latium vetus

To sum up, we first attempted to replicate some characterising features of the terrestrial route network of Latium vetus, as hypothesised from available archaeological and historical knowledge, using three previously elaborated models.¹³ It was not possible to attain entirely satisfactory results; in particular, none of these models was able to account for the observed concentration of long-range connections at few settlements. Hence, we modified one of these models – that is, the one that performed better in the Etruscan region – including a tunable amount of rich-get-richer bias, which improved considerably its performance.

Our results suggest that coordinated decision making with a slightly unbalanced power was responsible for the peculiar characteristics of the route network topology of the Latin region. This fits very well with the picture elaborated by different scholars on the nature of power balance and dynamics in the region. Latium vetus was organised in proto-urban centres and later city-states with a common material culture (Latial culture I–IV), similar burial costumes and a similar socio-political organisation. As well as for Etruria, Latin polities were characterised by cooperative/ competitive behaviours.¹⁴ However, the power was quite unbalanced.

In particular, it seems undeniable that by the end of the Early Iron Age 1 Early (EIA_{1E}) and the beginning of the EIA_{1L}, with the shift of the funerary areas from the Forum to the Esquiline and Quirinal Hill, Rome became by far the largest settlement in the region. Remarkably, in the period EIA_{1L}, Rome emerges as a hub in both the empirical network and the one generated by the biased model (EE-pa) (Fig. 7.7). Notice that, since the only information our models take from the empirical data are settlement locations, a place can only be favoured or disfavoured by its relative position with respect to other places. Therefore, such an outcome seems to confirm the hypothesis that the city occupied an advantageous position within the region.

7.3 Conclusions

In this chapter we use network analysis techniques developed for the study of spatial networks to characterise the system of Etruscan and Latin

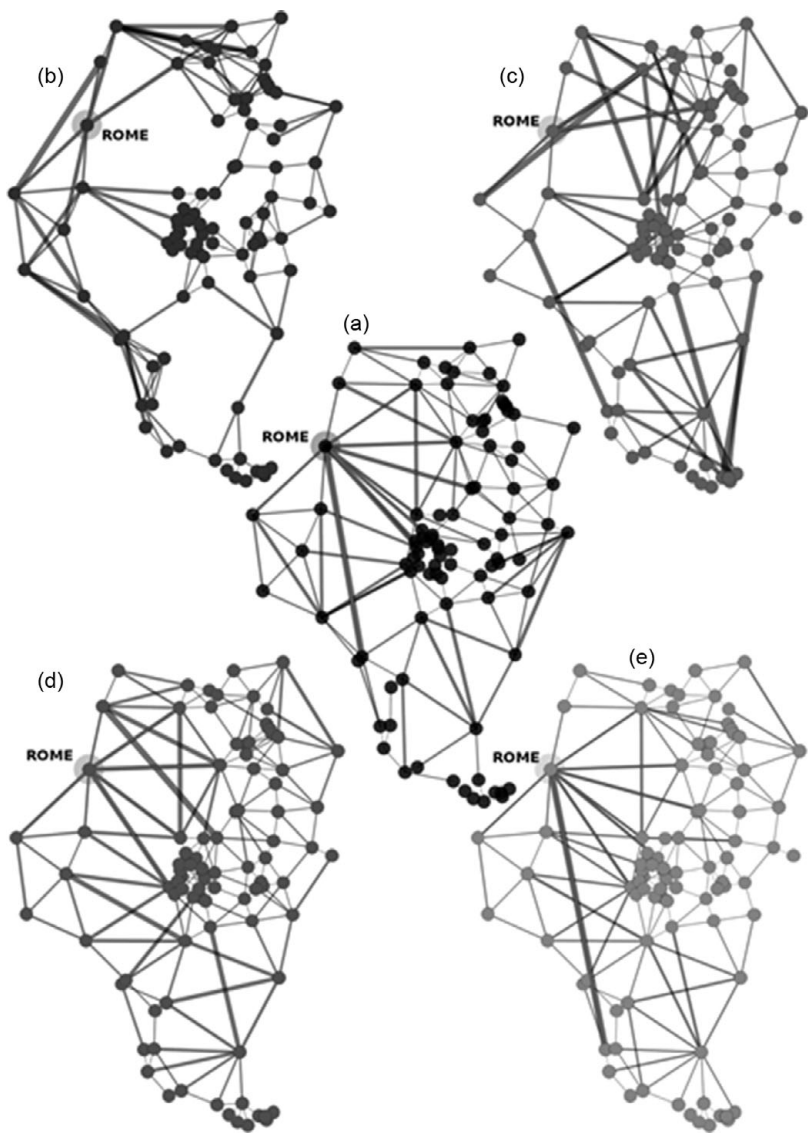


FIGURE 7.7. Networks of the EIAiL. (a) Empirical; (b) Best realisation of model L-L; (c) Best realisation of model G-L; (d) Model EE; (e) Model EE-pa (optimal value of a). Connections to the node Rome are marked in darker ticker line.

settlements terrestrial routes networks between the beginning of the Early Iron Age and the Archaic Period. Our main goal is to identify peculiar traits and patterns of these networks and then make hypotheses and build models

in order to determine which one fits reality the best. We found that the high global efficiency of the system and the increasing local efficiency are the peculiar features we are looking for and that we can use as a benchmark to test the models. A good model is a model that reproduces not only the peculiar features we are interested in, but also all the other basic characteristics of the systems. Simple models, with few parameters can be compared more easily.

We propose three simple ‘good network models’ corresponding to three different hypotheses about the mechanism underlying the creation of new connections. In the construction of the models, the settlements and their location are a fixed starting point. The models are built by a series of commands/rules that starting from a certain number of disconnected sites (the settlements of the empirical networks), defined which links would be created or not.

The first model implies that every node tries to connect to the highest number of nodes possible, with no specific strategy, but in a sort of blind competition, until its resources (the total length of the terrestrial routes in the system which is a fixed point in the empirical network) are exhausted. In this model the nodes, which can be considered as agents, are aware only of their direct neighbours.

In the second model, the nodes-agents are slightly ‘smarter’ (more information is available to them) and prefer to connect to those neighbours that are relatively more difficult to reach, that is, for which there does not already exist another reasonable route. In this way, the node-agents are aware of routes that exist also beyond their surroundings, that is routes that are passing through a third node (and possibly fourth, fifth etc.). The mechanism (basic competition) is the same as in model L-L, but the principle is different because each node chooses the new node to connect to not only on the base of linear distance, but on the knowledge of the all system.

The third model adopts the same criteria as the second, but the decision about which new connection to create is a global one. In other words, a level of ‘cooperation’ is introduced in the basic principle of coordinated prioritisation of new connections creation: each node-agent has its individual needs and priorities but the new links are created where they are most needed at the global level. The new connections are those that exist between long routes in comparison to their geographical distance. The information available to the node-agents is the same as in the second model, but their use is different. A global priority is negotiated that does not pursue local or individual interests (‘nobody is left behind’ to avoid weaknesses in the system).

As we will see in the discussion of the analyses, as long as it concerns southern Etruria the first two models capture some of the characteristic of the empirical networks but miss some others; the third model instead is able to reproduce with good accuracy all relevant characteristics for all periods considered, apart from a not negligible difference in the clustering coefficient: (1) decrease of average length; (2) non-monotonous increase of clustering coefficient; (3) constant global efficiency; (4) monotonous increase of local efficiency.¹⁵ Differently from Etruria, in Latium vetus each model reproduces some of the trends of the figures of the empirical networks but misses some others.

Therefore, in Latium vetus the second model, in which the node-agents' pursuit is of a personal interest of improving connectivity, seems to work better than in Etruria. However, the second and the third models (that works for southern Etruria), are not able to reproduce the situation existing in Latium vetus of some sites with many distant links, such as Rome. However, if the third model is slightly modified with the addition of the preferential attachment according to which 'the richest gets even richer' (that is the sites that have more links grow more and in turn attract more links in a feedback loop), then the model can reproduce the empirical situation with Rome and its numerous links. Specifically, we cannot be sure that any sort of (even weak) 'rich get richer' mechanism did not shape the Etruscan system. However, it seems to have been more prominent for the Latin system.

Certainly, Rome had other features that made it unique, for example, the capacity of the city of including strangers within its community.¹⁶ However, it is likely that its favourable location within the system of Latium vetus reinforced the concentration of power. Interestingly, the dissimilarities in the dynamics of power among city-states of Latium vetus and its neighbouring region of southern Etruria are reflected in the difference between the third model with added preferential attachment and the third model (i.e. the one best fitting the Etruscan case study). Indeed, Etruria during the Early Iron Age was dominated by a number of equally ranked proto-urban centres that went on to develop into the city-states of the Orientalising and Archaic Period (Veii, Tarquinia, Caere, Vulci, Orvieto and now also Bisenzio) characterised by a strong common identity but also by distinctive local 'flavours'. None of these centres were able to prevail over the others and impose on them a guiding role. Therefore, it has been suggested that at this time Etruria was characterised by a more balanced dynamic of power.¹⁷ This is consistent with the good performance of the third model which assumes an evenly distributed negotiating power among the settlements.¹⁸

Conclusions

Most regions and countries of the world are experiencing unprecedented demographic growth. Therefore, sustainable development of agglomerations and urban communities is one of the declared priorities of the United Nations in recent years and for the new few decades.

What is a city? And what can we do to improve the lifestyle of its inhabitants is a very pressing and urgent question. However, what is an ancient city? Whether we can establish any links between ancient and modern cities or whether defining what a city was in the past matters for the development and welfare of cities today is probably a different and more contentious question. Different people might have strong opinions about this that will polarise and/or exacerbate the debate. I hope this book, with its specific angle on transportation networks, will contribute to this debate, encourage the readers' curiosity and at the same time challenge and/or question their current views.

A number of recent projects have revitalised the debate on the ancient city, focusing either on the beginning of this phenomenon (the ancient Greek city, 'the Copenhagen Polis Centre' project), its ultimate legacy ('Reception of the City in Late Antiquity', Cambridge European Research Council funded project) and/or taking a long-term perspective and looking at its trajectory (from the origin to the Middle Ages, the 'OIKOS' network, or focusing from the Hellenistic Period to the Middle Ages, the UrbNet project). As discussed in Chapter 1, the recent book by Zuiderhoek has summarised in an intelligent and elegant discourse the longstanding debate on the ancient city.¹ To this is probably possible to add the discussion and a new perspective encouraged by a recent volume, I edited together with John Hanson, Scott Ortman and Luis Bettencourt on *Where Do Cities Come from and Where Are They Going to? Modelling*

Past and Present Agglomerations to Understand Urban Ways of Life, in *Frontiers Digital Humanities*.²

The magnitude of the challenges our cities face may be new, but in the past societies confronted many of these same issues. This is why we value the use of quantitative methods to understand the past. Some scholars are sceptical of comparative approaches and believe that comparisons between the past and the present require a level of generalisation that will imply the loss of specific characters and properties of past experiences.³ However, by carefully calibrating our modern models on the archaeological past,⁴ it is possible to distinguish the common universal pattern from the unique, specific traits of urbanism in past archaeological communities and modern societies.⁵ More specifically, by comparing past and present urban ways of life through the mean of quantitative approaches,⁶ we can create a dialectic by which present experiences can inform our understandings of the past, and the past, with its long trajectory, can help model the future.⁷

As shown in Chapter 2, I and other colleagues chose to focus on fluvial and terrestrial transportation systems analysed through the mean of the network science approach in order to analyse the economic potential and socio-political organisation of southern Etruria and Latium vetus between the Final Bronze Age and the Archaic Period. The identification of ancient roads and paths in the region has been the focus of traditional landscape and topographic archaeology at least since the last century; however, systemic approaches and quantitative perspectives had not been followed by any other scholar so far. Transportation systems are suitable for this purpose because in order to be created and/or used and maintained, they need a certain level of cooperation and integration among the polities that are connected by them, therefore they can provide clues on the political and socio-economic integration at the regional level. In addition, they can be analysed quantitatively and therefore are suitable for comparative approaches.

The network perspective as a heuristic tool and a metaphor has opened new perspectives in the study of ancient urbanism in central Italy and the Mediterranean more generally, thanks mostly to the work of scholars, such as John Wilkins,⁸ Robin Osborne,⁹ Irad Malkin¹⁰ and myself.¹¹ However, the application of network science and the use of networks as tool of analysis is proving even more powerful and engaging in a wide range of applications across different regions and chronological settings. Without pretending to be fully exhaustive, we could mention the work by Cyprian Broodbank¹² and Karl Knappet with Tim Evans and Ray Rivers on the Bronze Age Aegean,¹³ Eleftheria Paliou and Andrew Bevan on Bronze Age

Crete,¹⁴ Lauren Nunninger on settlement dynamics in Eastern Languedoc during the Iron Age¹⁵ and Søren M. Sindbæk on Viking maritime urban networks in Middle Age Scandinavia and Europe.¹⁶

With particular reference to transportation systems, the potential of network analysis has been applied to the analysis of communication systems and their interaction with economic dynamics and urban realizations in Mesopotamia during the 3rd millennium BC by Bjorn Menze and Jason Ur,¹⁷ the Latenian region during the Iron Age by Clara Filet,¹⁸ Iron Age south-western Germany by Oliver Nakoinz and Franziska Faupel,¹⁹ Roman Spain by Paulo de Soto,²⁰ Roman northern Italy²¹ and the Roman Dutch *Limes* by Mark Groenhuijzen and Philip Verhangen.²² The growing importance of transportation networks as a field of study in its own right is also confirmed by the proliferation of new projects such as ORBIS by Stanford University,²³ the New Transhumance project in Toscana²⁴ and the Mercator E-Project in Spain.²⁵

As shown in Chapter 3, southern Etruria and Latium vetus have provided an ideal set of data for quantitative comparative analyses based on network science approach for the intensity and spread of research conducted in the region and recently summarised in comprehensive studies and collective works. Settlement data, in particular, are very rich and detailed, while general complete, small-scale studies on transportation system are still lacking and we are planning to fill in this gap with further work. However, for the purpose of this study, large-scale maps have been used and the work of many different scholars has been consulted and collated in order to reconstruct the prehistoric and protohistoric routes of southern Etruria and Latium vetus for the purpose of network analysis. Methods applied in this work and synthetically illustrated in each chapter have been robustly developed in collaboration with network scientists and illustrated fully in previous papers to which we refer for greater details.²⁶

Chapter 4 showed that starting point of this work was the calculation of traditional centrality indexes in an exploratory and preliminary application. In line with other studies conducted in the same region during the same time period,²⁷ these analyses showed that fluvial communications were more relevant both for inter-communities interaction and settlement location during the Bronze Age, while with the subsequent Early Iron Age terrestrial communication became more important and were central for the development and prosperity of central places such as the large protohistoric centres that later will become the cities of the Archaic Period.²⁸ The discussion of this pioneering work with network scientists from Spain: Luce Prignano, Sergi Lozano and Ignacio Morer led also to the realisation

that distance among settlements was a key element to be able to take into consideration the cost of travelling in the application of the network analyses.²⁹ We are aware that this was probably a simplified choice compared to a more sophisticated use of GIS tools and least-path analysis but it was a conscious choice determined by the evaluation of the cost–benefit trade-off and the critiques and caveats recently proposed for discussion by various scholars about least-cost path analysis,³⁰ which are being overcome only very recently.³¹ Therefore, in all subsequent analyses and methods, when applicable, we weighted the different measures based on the total distance across the network.

The application of an ego-network approach and the calculation of centrality indexes for all major proto-urban centres in Etruria and Latium (that is those larger than 40–50 ha), showed that Rome generally performs slightly better than other centres but is not the absolute outlier. For example, another Latin centre, Gabii, also performs rather well. Another interesting observation is that Veii has similar but opposite trajectory to Rome in a later period, which is interesting considering the traditional historical sources and archaeological evidence have shown how these two centres were direct rivals and competitors on the opposite banks of the Tiber.

As well as the ego-network approach, the analysis of various efficiency indexes (weighted degree or strength, global efficiency, local efficiency and Smallest positive value of the eigenvalue of the weighted Laplacian matrix or algebraic connectivity (L_w), conducted in collaboration with Spanish colleagues and presented in Chapter 5, did not have clear cross-cutting results. The Latin region was slightly more efficient but not dramatically more efficient than the Etruscan region. However, the Latin region is more compact and the concentration of routes and/or the total amount of routes is comparatively higher and more dense than in Etruria. This might contribute to explaining why a smaller but more compacted and connected region such as Latium vetus in the end prevailed over a larger but less efficient Etruria.

The multi-scale perspective adopted in Chapter 6 represents still preliminary work that will be further developed. However, already this early stage of the research has provided some important results. Looking together at inter-regional connections and intra-site analysis has confirmed the importance of terrestrial routes for the development of proto-urban centres and later Archaic cities, as seems to be confirmed by the interpretation of Fora, as well as pre-Roman spaces for assembly, as a crossroad of busy activities and local but also regional and inter-regional contacts. We also looked at the Etruscan and Latin paths networks in relation to later Roman roads and

the initial impression is that Roman roads often re-used already existing branches of local connectivity. Thus, once again the ability of Rome was to adapt, incorporate and enhance something was already there.

Finally, the application of modelling techniques in Chapter 7 revealed that in Etruria the dominant model of interaction among centres seems to be a collaborative and rather even balancing of powers. In Latium vetus in contrast, there is still a basic form of collaboration among centres but, at some point, Rome emerges as a dominant centre and this changes the dynamics to a form of unbalanced distribution of power. This is consistent with previous interpretation of the political and socio-economic organisation of the two regions based on traditional archaeological and historical evidence.

While Etruria was composed of a number of more or less equal city-states (all between 100 and 200 ha) among which none was able to emerge over the others and impose its dominance over the region, Latium vetus. During the second phase of the earlier Early Iron Age (end of Latial Period IIA/beginning of Latial period IIB or around the end of the 10th–first half of the 9th century BC), Rome grew to become a centre similar in size to the other Etruscan counterparts (about 200 ha) and absolutely the major settlement in Latium vetus where all other major centres and central places ranged between 20–25 and 80–90 ha. Therefore, while for Etruria adopting the model of heterarchical organization been suggested, in Latium vetus a greater hierarchical model has been generally recognised.³²

Obviously, one must recognise many other important ideological and/or cultural aspects that favoured the advancement and the prosperity of the Roman polity, for example, as suggested by Mary Beard, its capacity of integrating foreigners and immigrants since the very beginning up to the Constantinian era.³³ However, we believe that Rome's specific favourable location within the Latium vetus system reinforced the concentration of power. Particularly, we hope this book has demonstrated that it was this position and the specific dynamics and relation to other polities in the region one of the key factors of its success and might explain why in the end Rome and not Veii prevailed.

Appendices: Data, Mathematical Explanations and Calculations

In the following appendices data, mathematical and statistical methods, and calculations of the analyses presented in the previous chapters and on which the conclusions of the book are evaluated, will be presented for full accessibility and replicability of the results.

APPENDIX A: MATHEMATICAL EXPLANATIONS AND CALCULATIONS FOR CHAPTER 5

Efficiency at the Global Level

To assess properly the efficiency and the functionality of the infrastructural systems of fluvial and terrestrial routes in southern Etruria and Latium vetus specific efficiency measures have been calculated. As explained in Chapter 5, a series of measures, introduced in the past fifteen years and related to the concept of efficiency of communication in networks embedded in a physical space, have been considered¹. As anticipated, in all these measures a weight has been introduced based on the linear distance between sites. In this way, it has been possible to take into consideration the effort encountered to move from one node to the other and to introduce a simple but effective proxy to account for the morphology of the region. The two areas in fact are geographically similar and rather homogeneous and therefore a linear distance is sufficient approximation for the physical variability of the environment². Both measures at the global and the local level have been considered. The first measure that has been considered at the global level is the global efficiency. This quantifies how well the information is exchanged across the whole network by assuming that the closer two sites are, the easier information is transferred between them. In its simplest definition, the efficiency of the communication between two sites is calculated as the inverse of the shortest path length – that is the minimum number of links – separating them³.

However, as mentioned above, dealing with geographic networks, we needed a definition that compares the best (ideal) path to the shortest path provided by the network. The shortest weighted path length L_{ij} between two sites i and j is the path with the lowest sum of distances, no matter the number of links in it. Consequently, a path of many steps

could be shorter than a path of just few steps if the sum of their lengths is smaller. Following Vragović and other authors⁴, we considered the geographic distance divided by the (weighted) shortest path length as an appropriate measure for the efficiency in the communication between two sites. The global efficiency of the network, E_{glob} , is calculated as the average over all pairs of nodes:

$$E_{\text{glob}} = \frac{1}{N(N-1)} \sum_{i \neq j} \frac{d_{ij}}{L_{ij}}$$

According to this definition, the global efficiency E_{glob} of a fully connected network – where every pair of nodes are connected – is equal to 1, no matter the number of nodes or their positions. To assess the possible existing alternatives to the best optimal available route, the normalised weighted Laplacian second (smallest) eigenvalue of the weighted Laplacian matrix has been calculated. This measure evaluates quantitatively the resilience of the infrastructure system at the global level. For further details and a mathematical explanation, we refer directly to Piet van Mieghem⁵.

Efficiency at the Local Level

At the local level two other measures have been considered. Firstly, the average strength has been considered. In fact, to assess the overall connectivity of the system, the spatial nature of the transportation network requires not only consideration of the amount of connections but also their length. The strength $\langle s \rangle$ extends the idea of node degree (number of connections) to the weighted case. Given a node i , $s(i)$ measures the total length of its adjacent links. The average $\langle s \rangle$ calculates then the average over the set of nodes. Given a node i , s_i measures the total length of its adjacent links⁶:

$$S_i = \sum_{j \in V} l_{ij}$$

where V is the set of neighbours of i , and l_{ij} is the length of the link between i and its neighbour j , that is, the distance between the two nodes. The average strength $\langle s \rangle$ is the mean value over the set of nodes:

$$\langle S \rangle = \frac{1}{N} \sum_{i=1}^N S_i$$

Secondly, the local efficiency of a node i , $E_{\text{loc}}(i)$, was proposed to quantify how well information is exchanged between its neighbours when that element is removed. This estimates how resilient a network is against localised failures. For example, if suddenly one of the nodes is not accessible anymore, what is the capacity of the neighbouring nodes to function and allow communication within the corrupted system?

We adopted the definition in Vragović and other authors⁷, devised specifically for geographic networks. Mathematically,

$$E_{\text{loc}}(i) = \frac{1}{K_i(K_i - 1)} \sum_{j \neq k \in V} \frac{d_{jk/i}}{L_{jk}}$$

where $d_{jk/i}$ is the path between j and k , both neighbours of i , if we remove i from the system. Averaging over all the nodes, a measure of the local efficiency (E_{loc}) of the network under consideration is obtained.

As will be discussed in Appendix B, adopting the above measures we were able to characterise the connectivity of the Etruscan and Latin system both at the local and global level and compare them objectively in order to understand if their starting point was after all so similar and/or if there were differences in their infrastructural systems that might explain the very different output of the two regions.

APPENDIX B: MODELLING FROM CHAPTER 7 STEP-BY-STEP

Measures for the Characterisation of the Empirical Networks

Usually, archaeological studies have looked at the local scale to hypothesise individual routes, looking at local evidence and geographical or environmental considerations to propose connections. In contrast, in the present work, we were interested in looking at such connections overall, that is, to the structure that they formed at the regional scale. By doing so, we could see a transportation network with peculiar features. The very first step for a proper characterisation of these systems was the description of the overall connectivity. To characterise the networks under study, we have selected five measures that are able to provide an almost exhaustive description of the connectivity pattern. In other words, given a set of nodes and their corresponding positions, it is nearly impossible to design two route networks that:

- a. have very **different values of at least one** of these measures, but are not also very different from each other (in terms of links that are present in one of them but not in the other, as well as in terms of qualitative visual appearance);
- b. have **similar values of all** the measures but are not also very similar (in terms of links that are present in both as well as in terms of visual appearance).

As state before in Appendix A, for the calculation of the efficiency indexes, here, the spatial nature of the transportation networks required not only the consideration of the number of connections but also their length.

The selected measures, chosen to characterise the networks are:

- i. average strength $\langle s \rangle$ (also known as average weighted degree $\langle kw \rangle$);
- ii. average edge length $\langle l \rangle$;

- iii. average (unweighted) clustering coefficient $\langle C \rangle$, that is, the average fraction of possible triangles through a node that exist (the fraction of neighbours that are connected to each other);
- iv. global efficiency $\langle E_{\text{glob}} \rangle$
- v. average local efficiency $\langle E_{\text{loc}} \rangle$

While the three two measures are very standard, the last two are not very commonly used. However, we consider that they are useful for the characterisation of communication infrastructure networks embedded in a physical space. Some of these measures have already been described in Appendix A, in relation to the calculation of the efficiency indexes but are here briefly revised for convenience of the reader.

The strength of a node $\langle s \rangle$ (also known as weighted degree $\langle kw \rangle$) extends the idea of node degree (number of connections) to the weighted case. Given a node i , $kw(i)$ measures the total length of its adjacent links¹. The average weighted degree $\langle kw \rangle$ calculates then the average over the set of nodes. Given a node i , S_i measures the total length of its adjacent links:

$$S_i = \sum_{j \in V} l_{ij}$$

where V is the set of neighbours of i , and l_{ij} is the length of the link between i and its neighbour j , that is, the (geodesic) distance between the two nodes. The average strength $\langle s \rangle$ is the mean value over the set of nodes:

$$\langle S \rangle = \frac{1}{N} \sum_{i=1}^N S_i$$

Next, it was informative to know the mean length of all the links. For example, considering the same amount of total length in a system, it could be distributed in lots of short edges or in very few long ones, which would imply quite different values of the mean length. The average edge length $\langle l \rangle$ is obtained by simply averaging the distance of all the links in the system:

$$\langle l \rangle = \frac{1}{M} \sum_{i=1}^N \sum_{j \in V_i} l_{ij}$$

where M is the total number of links in the network and V_i the set of neighbours of node i . Notice that these first two indices also provide the average degree $\langle k \rangle$, which is obtained by dividing $\langle s \rangle$ by $\langle l \rangle$.

Another classical property in network analysis, the clustering coefficient, describes the tendency of nodes to form dense groups (clusters). Given a node i , C_i indicates the proportion of all potential links between the neighbours of i that exist:

$$C_i = \frac{m_i}{k_i(k_i - 1)/2}$$

where m_i is the number of links connecting two neighbours of i , thus closing a triangle containing i . Averaging this ratio over the set of nodes, the average clustering coefficient $\langle C \rangle$ constitutes an indicator of the density of closed triangles in the network:

$$\langle C \rangle = \frac{1}{N} \sum_{i=1}^N C_i$$

A high (or at least, not negligible) clustering is commonly found in many real-world networks². The main point of calculating $\langle C \rangle$ is to indicate the probability that two neighbours of a site are also connected to each other. Hence, there is no need to use other definitions of clustering adapted to weighted networks. In the specific case of route networks, such coefficient indicates how often two settlements ‘choose’ to build a direct connection even if they are already connected through a common neighbour. Besides these generic metrics, we needed specific measures to capture the nature and functionality of these networks.

As illustrated in Chapter 4, the global efficiency of the network, E_{glob} , is calculated as the average over all pairs of nodes:

$$E_{glob} = \frac{1}{N(N-1)} \sum_{i \neq j} \frac{d_{ij}}{L_{ij}}$$

According to this definition, the global efficiency E_{glob} of a fully connected network – where each pair of nodes are connected – is equal to 1, no matter the number of nodes or their positions.

Similarly, in Chapter 4, the local efficiency of a node i , $E_{loc}(i)$, was proposed to quantify how well information is exchanged between its neighbours when that element is removed. This estimates how resilient a network is against localised failures. We adopted the definition in Vragović and other authors³, devised specifically for geographic networks. Mathematically,

$$E_{loc}(i) = \frac{1}{K_i(K_i - 1)} \sum_{j \neq k \in V} \frac{d_{jk/i}}{L_{jk}}$$

TABLE B.1. *Network properties of the empirical systems of the terrestrial routes networks for southern Etruria. For each period we report the system size N , the average strength $\langle s \rangle$, the average edge length $\langle l \rangle$, the cluster coefficient $\langle C \rangle$, the global efficiency $\langle E_{\text{glob}} \rangle$ and the local efficiency $\langle E_{\text{loc}} \rangle$.*

	EIA ₁ E	EIA ₁ L	EIA ₂	OA	AA
N	116	115	130	168	179
$\langle s \rangle$ or $\langle kw \rangle$ (km)	27.35	28.88	27.88	24.84	26.00
$\langle l \rangle$ (km)	7.792	8.021	7.711	6.631	6.287
$\langle C \rangle$	0.143	0.184	0.173	0.236	0.270
E_{glob}	0.875	0.887	0.869	0.872	0.888
E_{loc}	0.507	0.571	0.606	0.657	0.722

where $d_{j/k/i}$ is the path between j and k , both neighbours of i , if we removed i from the system. Averaging over all the nodes, a measure of the local efficiency (E_{loc}) of the network under consideration is obtained.

After exploring other network properties, we concluded that these four measures (i.e., $\langle l \rangle$, $\langle C \rangle$, $\langle E_{\text{glob}} \rangle$ and $\langle E_{\text{loc}} \rangle$) are adequate and sufficient to characterise the systems. The first three provided enough information about the overall connectivity (number and length of the connections, fraction of closed triangles), and the efficiency measures indicate to what extent the topology was suitable for certain dynamic processes (e.g., information exchange) taking place on the network. Table B.1 provides a characterisation of the empirical networks from these five structural features for southern Etruria as an example.

Explanations of the Models

Through the models we aim at reproducing synthetic versions of the networks we have constructed from empirical evidence, that is, the five networks of road in southern Etruria and Latium vetus in the five periods under study. The comparison will be between an empirical system (the ‘real’ network) and its corresponding synthetic versions (the networks generated through the models). The starting point for the generation of a synthetic version of a real network is the set of settlements and their corresponding geographic positions. In other words, the nodes are always the same, both in the empirical network and in its synthetic versions. The models are sets of rules that, starting from a set of disconnected nodes (the

settlements in the empirical system), determine which links do or do not exist. Hence, to compare an empirical network with its artificial counterpart means we are comparing the links of networks whose nodes are identical (in number, names and positions).

Model L-L. Local Information, Local Decision Making

The first model was inspired by the simplest hypothesis of all, so simple that it could be regarded as a ‘null-hypothesis’: sites individually competed to gain the largest portion of resources (i.e., connection length). In this model, each node (that can be regarded as an ‘agent’ even though in a broad sense) is aware of its surroundings alone. They know where the closest settlements are located and whether they are directly connected to them or not. Whenever they have the chance, they create a connection (link) with a new neighbour, always choosing the one at the shortest distances among those that are not directly connected to them yet, regardless of whether:

- a) There is an already existing path connecting them through other settlements that is just slightly longer than the direct connection
- b) At a slightly longer (geographical) distance, there is another settlement that is difficult to reach (the existing path is very long) or even impossible to get to.

We simulated the idea exposed above by extracting a random node and connecting it with the nearest not connected one. We repeat this action until the sum of all the link lengths reaches that of the empirical system, we are modelling. Some nodes will be ‘luckier’ and get more links, some others may get fewer. Each realisation of the process gives a different output: there will never be two identical networks, but all of them will share some common features. In other words, each realisation gives a different output at the microscopic level, but they all belong to the same macro-class of networks.

Model G-L. Global Information, Local Decision Making

In this second model, nodes had information about direct connections to local neighbours (as in model L-L) as well as indirect connections to other nodes (i.e., paths including one or more intermediate nodes). The procedure to create links mimicked that of model L-L, but the criterion considered in step 2 changed in order to capture the additional information

available to settlements. Hence, instead of always choosing the nearest geographical neighbour, the model considers a normalised distance R that is calculated as follows:

$$R_i(j) = R_i(i) = d_{ij}L_{ij}$$

Where d_{ij} is the geographic distance between node i and node j , and L_{ij} is the length of the shortest existing path between them. Accordingly, model G-L followed these steps:

1. A node i was drawn at random from the total population.
2. $R_i(j)$ values were computed for all nodes j in the system (except for i).
3. The node j^* with the minimum R_i was selected and a link between i and that node j^* was created.

The function $R_i(j)$ balances costs and benefits, prioritising those links that shorten long paths (large L_{ij}) while wasting little resources (short d_{ij}). As in model L-L, steps 1, 2 and 3 were repeated until the sum of all the link lengths reached that of the empirical system being modelled. Notice that, in principle, nodes provided with more information than in model L-L should be able to make ‘clever’ decisions limiting the waste of resources (i.e., creating roads making non-significant contributions). Once again, the model had a stochastic component, that is, it was partially ruled by chance. Therefore, each realisation had its own microscopic characteristics, but all of them shared some macroscopic commonalities.

Model EE. The Equitable Efficiency Model

This third model not only provided nodes with global information about their connectivity, but also with the ability to make coordinated decisions. More concretely, each settlement knows the length of each one of the existing paths between its location and any other settlements, as in model G-L, but this time they prioritised links globally according to their $R_i(j)$ value. The exact procedure of model EE is the following:

1. For each node i , all the $R_i(j)$ values were calculated.
2. Each node i proposed the creation of a link between itself and a node j^* such that the $R_i(j^*)$ was the minimum value among all the $R_i(j)$ (local interest expressed by node i).
3. All the proposals were ranked according to their R value and a link was created between the pair corresponding to the global minimum (coordinated decision-making).

Step 1, 2 and 3 were repeated until the summed lengths of all created links reached that of the empirical system. The existence of a global priority list instead of individual, local ones emulated a certain degree of coordination among the settlements in the sense of a general intention of preventing weak points in the network. In this way, without altering the nature of the interests of each settlement that were still local, we introduced a balancing mechanism to smooth out the effect of competition. Even though this model did not explicitly optimise any global metric, and therefore could not be regarded as a model of global planning for the infrastructure, the coordinated decision making made it different from the previous ones in a very fundamental aspect. As explained above, L-L and G-L models were stochastic because the focal node i was chosen at random.

This was not the case in the EE model, since links were established between the pairs of nodes i and j that minimise $R(i,j)$ at each step. Chance did not play any role in this algorithm, which implies that the model's final output was unequivocally determined: for each empirical network, model EE generated a unique artificial counterpart. As an illustrative example of the kind of connection patterns generated by the three models, in Fig. 7.1 in the text and Fig. B.1 we have represented the empirical network of Age EIAI L with its artificial counterparts: one realisation of models L-L and G-L and the output of the EE model.

Explanations of the Analyses

Testing of the Models for Southern Etruria

To validate the three proposed models, we tested whether the synthetic networks that they generated were capable of reproducing the structural features (i.e., the average edge length $\langle l \rangle$, the cluster coefficient $\langle C \rangle$, the global efficiency $\langle E_{\text{glob}} \rangle$ and the local efficiency $\langle E_{\text{loc}} \rangle$). We

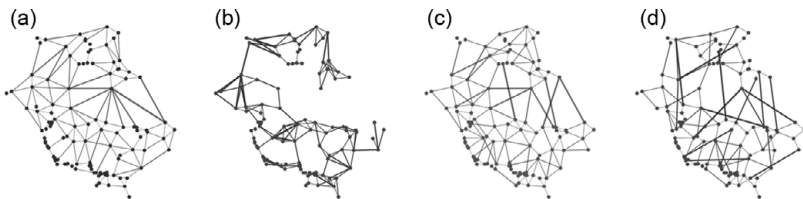


FIGURE B.1. Example of network realisations: networks of EIAI L. (a) Empirical; (b) a random characteristic realisation of model L-L; (c) a random characteristic realisation of model G-L; (d) model EE.

applied the models to southern Etruria first. As discussed above, we were not aiming to reproduce each and all connections. Our goal was to explain those features of the overall topology previously selected for their relevance in determining the performance of a transportation network. This approach has an additional advantage when validating the models using empirical networks: It is not dependent on local individual details of the empirical networks. As already explained, terrestrial routes were inferred from a vast and heterogeneous amount of information. While first order connections among main primary centres (cities) are more certain, local connections among small villages might have slightly different interpretations. This uncertainty undermines the utility of validation by comparing individual connections one by one. On the contrary, average properties of the connectivity pattern would not change noticeably if a few of the routes were different from those considered here. Indeed, since our approach relies on system-scale information, we did not need the route map to be perfectly accurate for this methodology to be applied.

Network Properties: Southern Etruria Figs. B.2 and B.3, on the other hand, show separately, the comparison of the properties calculated for the empirical networks and the output of the models along the five ages for southern Etruria. Given that model L-L and G-L are stochastic, we had to average over several realisations (repetitions of the modelling process) to obtain representative outputs. The number of realisations for each model and Age was not fixed a priori. We kept generating new ones until all the average values of all the considered metrics and their standard deviations stabilised within an error of 1%.

While significant differences with the empirical networks were observed in the cases of model L-L and model G-L, the EE model was able to recreate with good accuracy the relevant features for all five considered periods. In particular:

1. When comparing with the empirical networks, the average edge length ($\langle l \rangle$) was generally lower for networks produced through model L-L and higher for networks produced by model G-L. This is due to the fact that nodes in model L-L tended to connect with those that were geographically close to them. On the contrary, in model G-L, if drawn more than once, they looked for shortcuts towards nodes that lie at greater distances. As for model EE, the obtained values were intermediate and close to those of the empirical networks, the largest difference being found in the first period

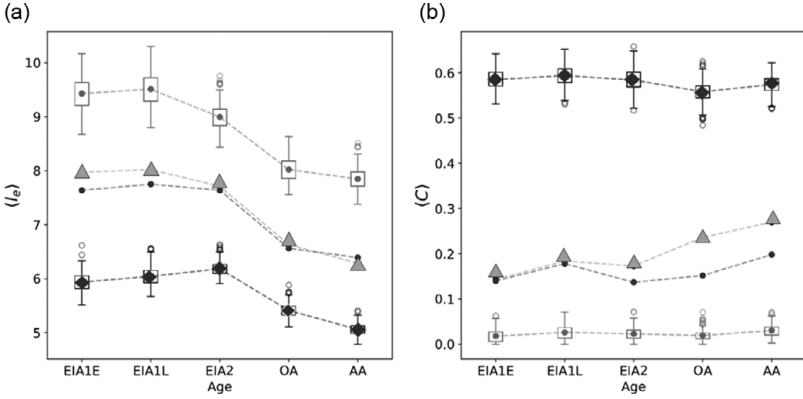


FIGURE B.2. Values of $\langle L \rangle$ (a) and $\langle C \rangle$ (b) for the empirical and synthetic networks of southern Etruria: empirical network grey triangles, model L-L black diamonds, model G-L grey dots, model EE black dots. Points stand for average values, boxes span from the lower to the upper quartile values, and whiskers show the range of data.

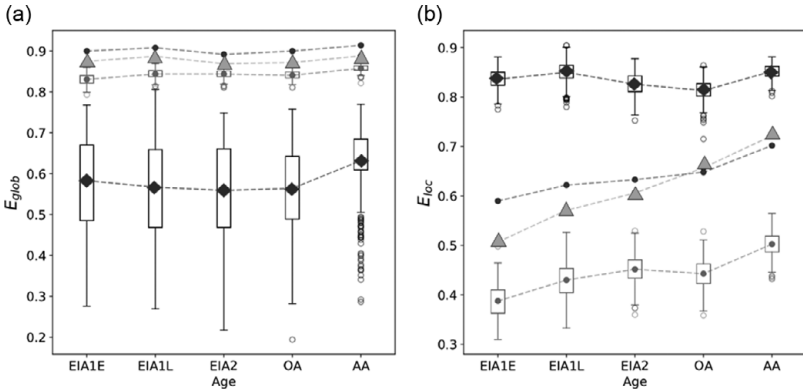


FIGURE B.3. Values of E_{glob} and E_{loc} for the empirical and synthetic networks. See Fig. B.2 for more details.

(up to 4.2% with respect to the empirical value). In the later ages, this deviation decreased, becoming nearly imperceptible in the last three. In model EE, nodes tried to create shortcuts as in model G-L, but the prioritisation mechanism forced the construction of the shortest ones first.

2. The average cluster coefficient $\langle C \rangle$ was not reproduced correctly by either L-L or G-L models. With the L-L model we obtained values that were (on average) two or three times the empirical corresponding ones. This difference was higher for the first period (EIA1E), but

it progressively diminished for later periods, as the value of $\langle C \rangle$ in the empirical system tended to increase through time while in the artificial networks it is kept constant. It is worth noting that, since two nodes close to a third one, are also close to each other, model L-L naturally created many triangles, that is, networks with a very high clustering coefficient. As for model G-L, since the combination of random node selection and shortcuts were very unlikely to close triangles, its synthetic networks presented negligible values of clustering coefficient. Again, model EE provided the best results. It was the only outcome that reached values close to empirical ones (especially in EIA1E and EIA1L), although appreciable differences were spotted during the Orientalising and Archaic periods.

3. In the case of model L-L, global efficiency $\langle E_{\text{glob}} \rangle$ was almost always lower than that of the empirical networks. Specifically, obtained values presented a high variability across realisations, and very few of them reached values close to the empirical ones. Since, according to this model, nodes had no cognition of the global scale, a good result in terms of global efficiency might occasionally be achieved by chance. On the contrary, the G-L model produced networks whose $\langle E_{\text{glob}} \rangle$ was almost identical to that of their empirical correspondents (usually slightly lower) with extremely limited fluctuations. Networks obtained with model EE also showed similar values of $\langle E_{\text{glob}} \rangle$ and, as opposed to model G-L, they turned out to be slightly more efficient.
4. The values of the local efficiency $\langle E_{\text{loc}} \rangle$ in synthetic networks produced by model L-L were significantly higher than those of their empirical counterparts. It was just the opposite for the values obtained from synthetic networks produced by model G-L, which were lower. The closest approximation to $\langle E_{\text{loc}} \rangle$ was yielded once more by the EE model. The agreement with the local efficiencies of reference is particularly precise after EIA2. For the first Age only, when model G-L and model EE were practically equidistant to the target value, none of the models could provide completely satisfactory results.

Summarising, model L-L had the best local connectivity (high $\langle C \rangle$ and $\langle E_{\text{loc}} \rangle$), but performed very poorly at the global scale (low $\langle E_{\text{glob}} \rangle$), while model G-L was weaker at the local scale (low E_{loc} , non-existent $\langle C \rangle$), but quite efficient at the global level. More interestingly, model EE displayed the highest values of global efficiency, while doing reasonably

well in terms of local efficiency. Both in model G-L and in model EE, nodes explicitly sought to increase the global efficiency by means of the creation of shortcuts. However, the clever, thrifty use of resources implemented in the EE model, prioritised shorter links. The improvement in the connectivity at the local scale was obtained as a useful by product.

Network Difference for Southern Etruria

The previous subsections revealed successful and unsuccessful aspects of each model and seemed to place the EE model and its coordinated decision making ahead of the models that included a competitive mechanism. However, evaluating the performance of the models by merely looking at the properties one by one is not accurate-enough. To assess the overall agreement between the properties of empirical and synthetic networks (i.e., by considering all four of them at once), we defined the following difference function D:

$$D = \frac{1}{4} \left(\frac{\langle l \rangle^e - \langle l \rangle^s}{\langle l \rangle^e} + |\langle C \rangle^e - \langle C \rangle^s| + |E_{\text{glob}}^e - E_{\text{glob}}^s| + E_{\text{loc}}^e - E_{\text{loc}}^s \right)$$

where e and s indices stand for empirical and synthetic networks respectively. According to this expression, the difference between two networks is the average of the absolute differences of the four characterisation measures. The only measure not defined in the range $[0,1]$, the average link length, was normalised dividing by its value in the empirical system. Fig. B.4 shows the behaviour of the three models in terms of the difference D across the ages. The deterministic model provided the smallest D for every age. The initial period EIA1E showed the smallest difference between model G-L and model EE. In fact, this was the only moment in which a few runs (around 1%) of model G-L produced similar values of the difference function. In general, we can conclude that, through time, the EE model consistently outperformed the others.

Evaluation of the results: Southern Etruria

Observing how close the behaviour of model EE is to that of the empirical networks, our results suggest that this mechanism for the creation of connections resembles, although in an extremely simplified way, the essence of transportation network configuration in Etruria during the Iron Age. Although it is always possible that a different model (implementing different mechanisms) would also recover the features of the empirical road

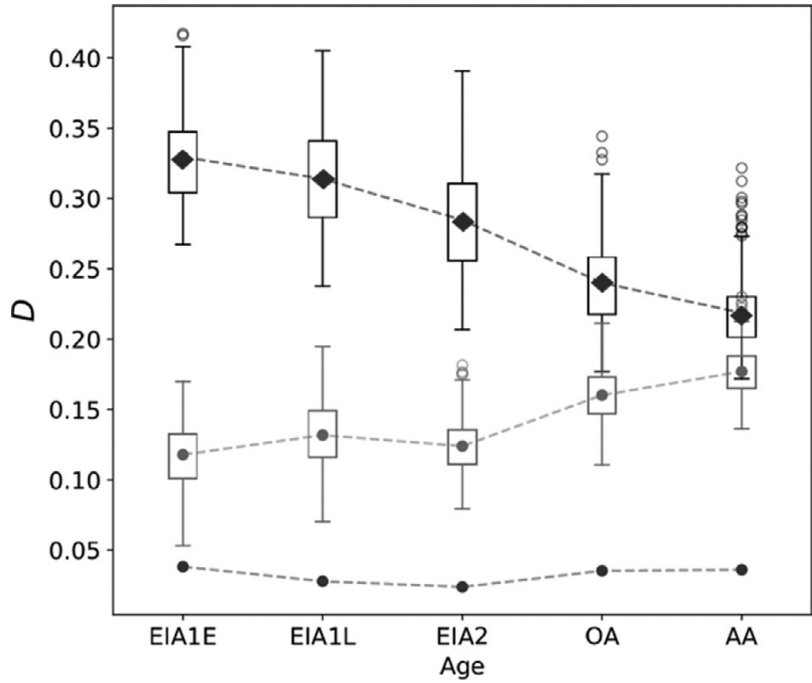


FIGURE B.4. Difference D between the empirical and the synthetic networks. Black dots model E-E, black diamonds model L-L, grey dots model G-L.

connections, from a general historical viewpoint, our model represents a realistic scenario. It is reasonable that cities and towns from those times were interested in being connected to each other, knew their individual necessities and shared such information at the regional scale. It is also worth noting that the underlying assumption about what the node-polities knew – which is the same in both model EE and model G-L – is also realistic.

Indeed, models G-L and EE do not assume that cities had a complete knowledge on the state of the whole system at each moment, which is a kind of information that would have hardly been available to them. On the contrary, according to these two models, each one of them only knew its own situation with respect to all the other sites, that is, had a complete subjective map of the territory, and tried to improve its connectivity in the most profitable way. When considering the details of the EE model, the hypothesis that local interests were sorted according to a more general (global) assessment of the overall functioning of the region is compatible with the existence of a league of loosely cooperating independent

city-states. To hypothesise a general common criterion that guided consensus about how resources had to be allocated when dealing with something as fundamental as roads, is perfectly plausible in this scenario.

Testing of the Models: . . . and Latium vetus?

When we applied the same three models to Latium vetus something interesting happened. Figs. 7.5 and 7.6 show the comparison between empirical networks at each Age and their synthetic equivalents. While model G-L seems to perform the best concerning the average edge length ($\langle l \rangle$), model EE is better at reproducing average clustering coefficient values (Fig. 7.5, b). Interestingly enough, Fig. 7.6 shows that networks generated by model EE are more efficient (both globally and locally) than empirical networks in all ages. Focusing on global efficiency, networks generated by model G-L are most similar to the empirical ones. However, for some ages (i.e., EIA2 and OA), outputs of model L-L (the less globally efficient one) are more similar.

Regarding local efficiency (Fig. 7.6, b), model G-L reproduces almost perfectly the empirical values. Generally model G-L seems to be the most accurate at reproducing the empirically observed behaviours, but it fails with the average clustering coefficient. On the contrary, model EE is the only one generating values, close to the empirical ones for this magnitude. These results suggest that, in this case, the real mechanism at work was a combination of models G-L and EE. Model EE is just one specific realisation of model G-L. Once the focal node is selected, the criterion for determining links selection is the same for models G-L and EE, namely minimising the ratio $r = d/L$, where d is the length of the link to be created and L that of the shortest path already existing between the two nodes. What makes models G-L and EE different is the prioritisation of nodes to be the focal one. In model G-L, all nodes have the same probability of being selected. Model EE prioritises the node minimising r all over the system.

Nevertheless, the likelihood of model G-L generating the same synthetic networks as model EE is negligible because there is a huge number of alternative orderings ($N! \cdot 10^{157}$). Moreover, because of the peculiarity of the ordering criterion in model EE, these synthetic networks happen to be outliers whose values of the considered measures lie even three to four standard deviations away from the average of model G-L (see Figs. B.5 and B.6). This very particular prioritisation of nodes can explain why in model EE the values of average clustering coefficient is higher than in networks

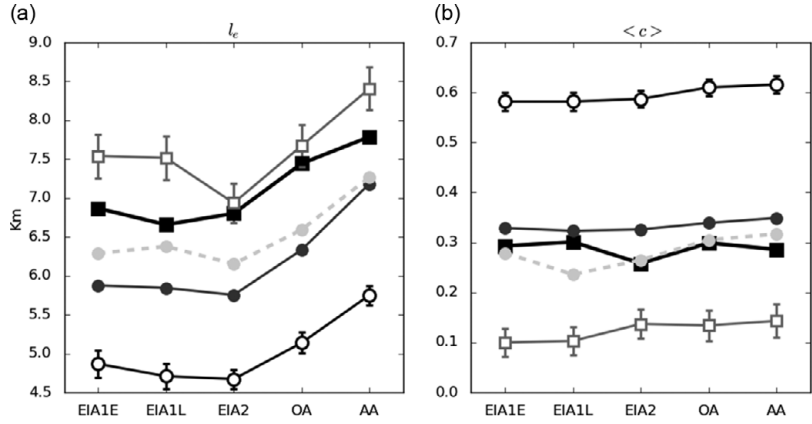


FIGURE B.5. Average edge length ($\langle l \rangle$) (a) and average clustering coefficient ($\langle C \rangle$) (b). Legend: empirical network (black filled squares); averaged output of model 1 (L-L) (black open circles); averaged output of model 2 (G-L) (grey open squares); output of model EE (black filled circles); averaged output of model EE-pa (light grey filled circles and dashed line).

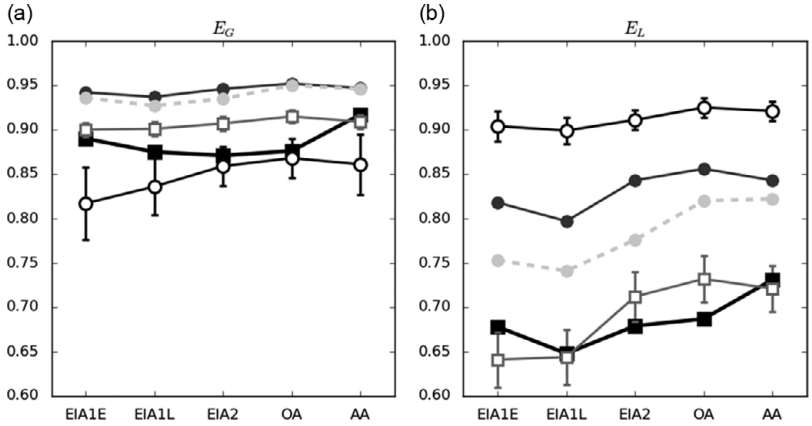


FIGURE B.6. Global efficiency (E_{glob}) (a) and local efficiency (E_{loc}) (b). Legend: empirical network (black filled squares); averaged output of model L-L (black open circles); averaged output of model G-L (grey open squares); output of model EE (black filled circles); averaged output of model EE-pa (light grey filled circles and dashed line).

generated by model G-L. To summarise, although both model G-L and model EE capture some of the empirical features, none of them are satisfactory enough. It is noteworthy that the advantages of one correspond to the flaws of the other and vice-versa, suggesting that a model placed somewhere

between these two could satisfy our needs. Therefore, it becomes necessary to understand where and why models G-L and EE fail to explore our options.

Elaboration of a Modified Model with the Criterion of the Preferential Attachment

A model explaining Latium vetus networks better should keep this convenient principle of global ordering of nodes but should change the specific criterion adopted. By modifying the ordering criterion, we could, in principle, interpolate between the average properties of networks of model G-L and this special outlier that is model EE. However, we need some clues to modify the node ordering in a desirable way. To gain insight in this line, we take a closer look at both synthetic and empirical networks and especially to their weighted degree and edge length distributions. Fig. B.7 shows the standard deviation of the strength (or weighted degree). In this case, model EE results (black circles) are much closer to the realisations of model G-L (grey open squares). Both models produce networks whose diversity among nodes in terms of weighted degree is much smaller than that observed empirically. For the link length distribution, we adopt a slightly different approach. We want to know where model G-L is failing, even when considering its best realisation. Hence, we need a definition of what such a best realisation is. We define a modified distance D' between an empirical network and a corresponding synthetic one as:

$$D' = \frac{1}{5} \left(\frac{\langle l \rangle^e - \langle l \rangle^s}{\langle l \rangle^e} + | \langle C \rangle^e - \langle C \rangle^s | + | E_{\text{glob}}^e - E_{\text{glob}}^s | \right. \\ \left. + | E_{\text{loc}}^e - E_{\text{loc}}^s | + \left| \frac{\sigma((k_w)^e - \sigma((k_w)^s)}{\sigma((k_w)^e)} \right| \right)$$

where e and s labels refer to the empirical and synthetic networks, respectively. According to this formula, distance D' is obtained as the average of the absolute differences between the values of the quantities used for their characterisation, the original four (included in the definition of the original distance D) plus the standard deviation of the weighted degree distribution. For quantities that are not defined in the range $[0, 1]$, we normalise by dividing the difference by the value calculated for the empirical network. We use this distance definition to select the synthetic networks generated by model G-L that were the closest to the corresponding empirical ones.

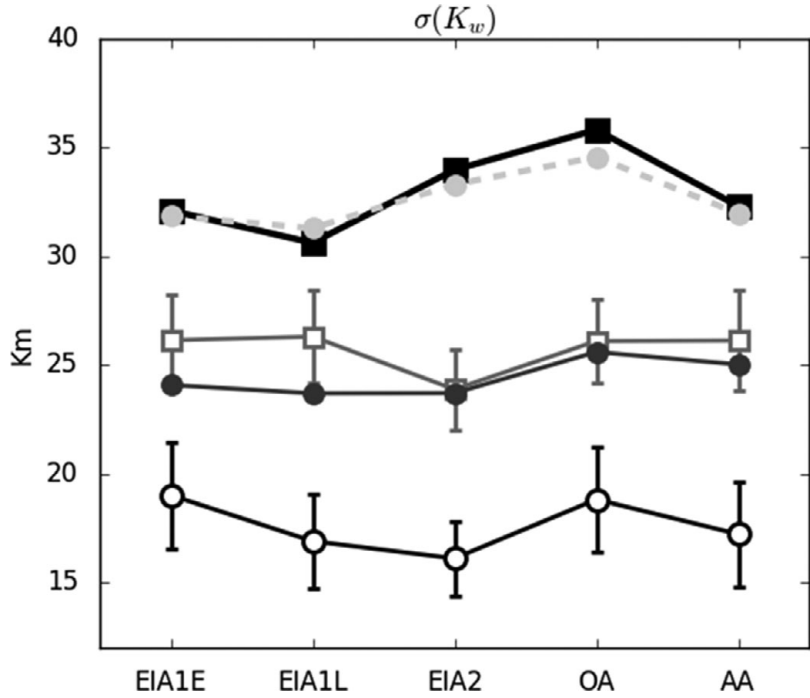


FIGURE B.7. Standard deviation of the weighted degree of nodes. Legend: empirical network (black filled squares); averaged output of model L-L (black open circles); averaged output of model G-L (grey open squares); output of model EE (black filled circles); averaged output of model EE-pa (light grey filled circles and dashed line).

Then, we compare their edge length distribution with that of both empirical networks and model EE synthetic networks. In Fig. B.1, we show the boxplot of the edge lengths for ages EIA2 and OA, the two periods when the empirical average of the edge length is almost perfectly reproduced by model G-L. When compared to the empirical ones, networks generated by model G-L present a similar average length but also many extreme outliers (i.e., with length values up to five times larger than the mean). On the contrary, model EE has a lower mean but similar maximum. Taking into account these results, we conclude that empirical networks have (a) a weighted degree distribution more skewed than that of networks generated by in models G-L and EE and (b) an edge length distribution less skewed than the one generated by model G-L but more than in model EE.

Consequently, in terms of identifying mechanisms capable of reproducing our empirical networks, this suggests that we are looking for a mechanism allowing the nodes to accumulate an increasing amount of

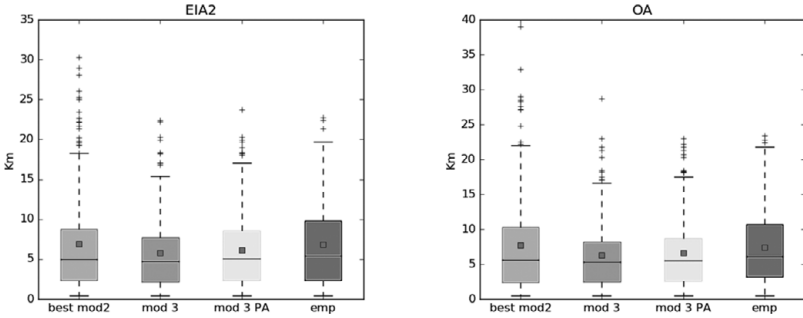


FIGURE B.8. Edge length distribution of the artificial and empirical networks in EIA2 and OA.

connections up to a certain limit. In other words, we need nodes to compete for connections (but to a lesser degree than in model G-L), in such a way that a few privileged nodes could accumulate most of the connections. There are obviously many ways to implement this general framework and many possible interpretations of what being a privileged node means. However, in the present study, we are interested in exploring the idea of privilege understood as the importance of a node in terms of some network measure (Fig. B.8).

Such property would make some nodes more powerful and capable of imposing their priorities when new connections are built, thus increasing their importance even more in a positive feedback loop. Our models simulate the progressive addition of new links connecting a given set of initially disconnected nodes, but we are not reproducing the time evolution of the network. Each of the steps of this growth corresponds to a mature state of the network but with fewer resources (total link length). Hence, the initial stages of the process correspond to less economically prosperous systems, not to younger ones; and the first links that the algorithms create have to be regarded as the most necessary connections, and not as the oldest ones. In this sense, if a node is important when the growth starts, this means it is decisive when the economic situation in the region is not good. We intend such condition as an advantage that confers privileges when the system flourishes again.

In network science this mechanism is usually called preferential attachment and the measure of the importance of the nodes is their weighted degree, also called ‘node strength’⁴. The basic idea is that link creation considers the ‘power’ acquired by nodes up to that point and gives a higher priority for the creation of further connections to those

nodes that have a weighted degree above the average. We modified model EE by adding preferential attachment (pa) to its link generation mechanism (EE-pa). More precisely, in model EE-pa, each node proposes the connection that is most necessary from its point of view, but the decision about which one is the next to be built is made considering two factors. On the one hand, we consider the objective need for that link (i.e., the value of r); on the other hand, we also include in the equation the importance of the proposing node. The larger its weighted degree, the higher the priority of the link. Mathematically, such a bias is obtained by weighting the ratio r with a (negative) power of weighted degree of the proposing node. The trade-off between the two ingredients in determining the priority of each link is tuned by the exponent a of such power. Hence, the new value of the biased ratio r' for a connection between node i and j proposed by node i is

$$r'_{ij} = r'_{ij}k_w(i)^{-a} = \frac{d_{ij}}{L_{ij}}k_w(i)^{-a}$$

where d_{ij} and L_{ij} are, respectively, the geodesic distance and the shortest weighted path length between them and $k_w(i)$ is the weighted degree of node i .

When a is equal to zero, there is no preferential attachment and we recover model EE. By varying its value, starting from $a = 0$, one can generate networks with an increasingly biased link prioritisation.

For each age, we select the value of a that generates the synthetic network whose distance to the corresponding empirical system (according to equation of D') was minimal. Table B.2 shows the obtained optimal values for the parameter a . Then, we compute all the structural measures for each one of these configurations of model EE-pa. By comparing these results with those corresponding to models GL and EE, we identify the following points in favour of the new model:

TABLE B.2. *Values of the preferential attachment parameter a that generate the best synthetic network (the one with the shortest distance D to the empirical one) for each period.*

EIA1E	EIA1L	EIA2	OA	AA
0.09	0.11	0.10	0.08	0.06

1. It captures important features of the empirical system that none of the previous models could reproduce, as for instance the standard deviation of the weighted degree (see Fig. B.7).
2. Although model EE was already pretty good at reproducing the average clustering coefficient, the new model performs even better (see Fig. 7.5, left).
3. It is almost as good as model G-L at reproducing the average link length without the shortcoming of having some extreme outliers (see Fig. 7.5, right, and Fig. B.1).
4. Consequently, it is the model with the shortest distance D' from the empirical network for all the five ages (Fig. B.9).

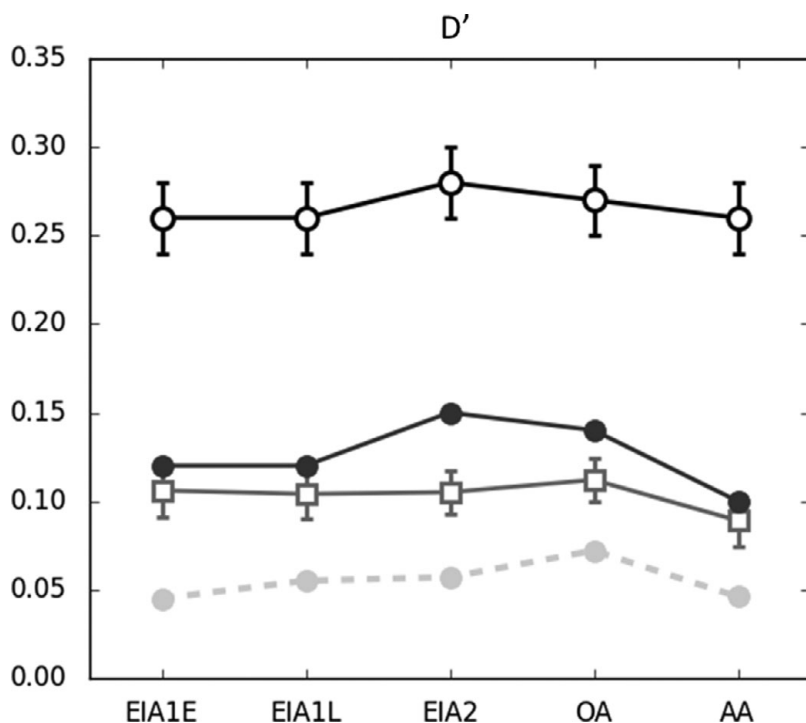


FIGURE B.9. Distance D' from the corresponding empirical networks. Error bars represent the standard deviation from average for the non-deterministic models. Legend: empirical network (black filled squares); averaged output of model L-L (black open circles); averaged output of model G-L (grey open squares); output of model EE (black filled circles); averaged output of model EE-pa (light grey filled circles and dashed line).

5. Overall visual inspection reveals that synthetic networks generated this way look similar to the empirical ones, displaying the typical combination of small triangles and polygons along with few radial structures of larger connections (Fig. B.10).
6. It reproduces interesting structural characteristics around Rome. In particular, the city appears at the centre of the most evident radial structure (see Fig. B.3, and it is also the node with the largest weighted degree in the EIA₁L when the average is $\langle k_w \rangle = (28.39 \pm 31.29)$ km and k_w (Rome) = 192.2 km.

Summarising, the best model is a modified version of model EE that includes weak preferential attachment (i.e., a takes small values).

Synthetic Evaluation of the Results: Latium Vetus

We first attempted to replicate some characterising features of the terrestrial route network of Latium vetus, as hypothesised from available archaeological and historical knowledge, using three previously elaborated models⁵. It was not possible to attain entirely satisfactory results; in particular, none of these models was able to account for the observed concentration of long-range connections at few settlements. Hence, we modified one of these models – that is, the one that performed better in the Etruscan region – including a tuneable amount of rich-get-richer bias, which improved considerably its performance.

Our results suggest that coordinated decision making with a slightly unbalanced power was responsible for the peculiar characteristics of the route network topology of the Latin region. This fits very well with the picture elaborated by different scholars on the nature of power balance and dynamics in the region. Latium vetus was organised in proto-urban centres and later city-states with a common material culture (Latial culture I–IV), similar burial costumes and a similar socio-political organisation. As well as for Etruria, Latin polities were characterised by cooperative/competitive behaviours⁶. However, the power was quite unbalanced. In particular, it seems undeniable that by the end of the EIA₁E and the beginning of the EIA₁L, with the shift of the funerary areas from the Forum to the Esquiline and Quirinal Hill, Rome became by far the largest settlement in the region. Remarkably, in the period EIA₁L, Rome emerges as a hub in both the empirical network and the one generated by the biased model (EE-pa). Notice that, since the only information our models take from the empirical data are settlement

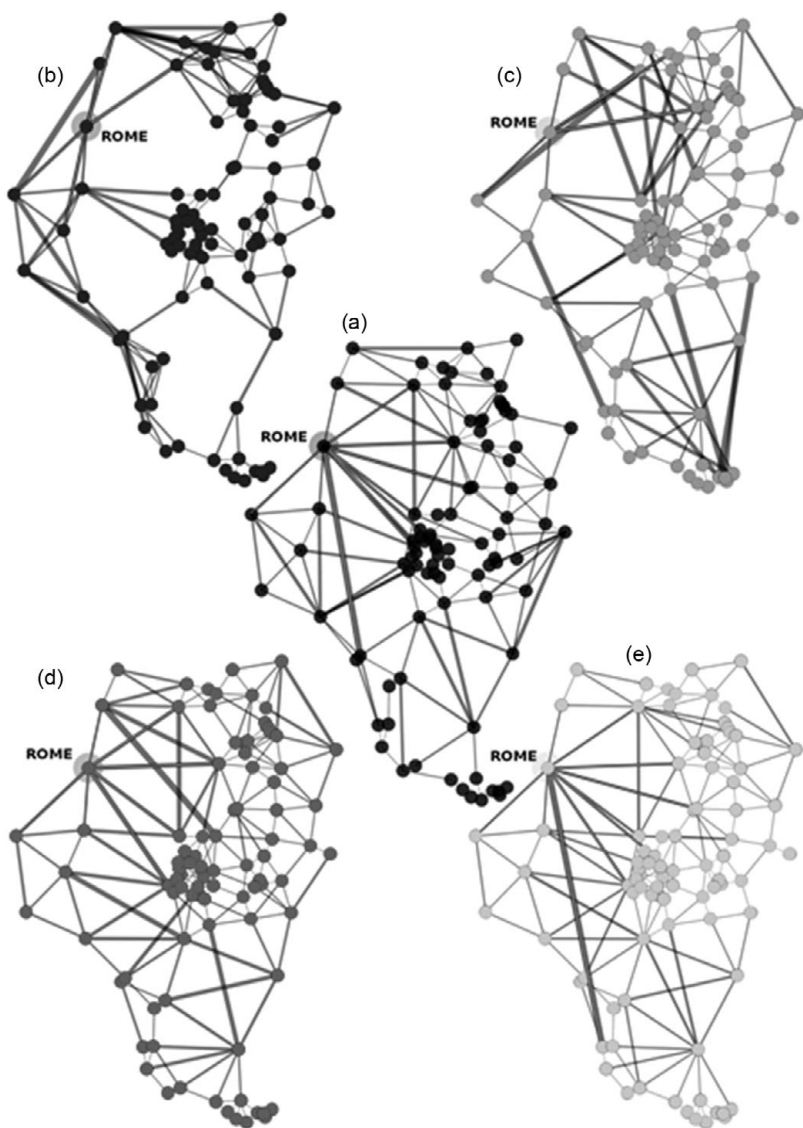


FIGURE B.10. Networks of the EIA11. (a): empirical; (b) best realisation of model L-L; (c) best realisation of model G-L; (d) model E-E; (e) model E-E-pa (optimal value of a). Connections to the node Rome are highlighted in heavy dash.

locations, a place can only be favoured or disfavoured by its relative position with respect to other places. Therefore, such an outcome seems to confirm the hypothesis that the city occupied an advantageous position within the region.

APPENDIX C: MATHEMATICAL EXPLANATIONS AND CALCULATIONS FOR CHAPTER 4

Betweenness Centrality

Betweenness centrality indicates the degree to which an actor controls or mediates the ‘relations between other pairs or dyads of actors that are not directly connected. Actor betweenness centrality measures the extent to which other actors lie on the geodesic path (or the shortest distance), between pairs of actors in the network’¹. At this point it ought to be noted that distance in a network is not a geographical distance but the number of links which connects two nodes. In other words, the betweenness centrality measure the extent to which a node or actor lie on the shortest route connecting each pair of other nodes/actors in the network². As originally proposed by Freeman, betweenness centrality is given by the formula:

$$C_B(N_i) = \sum_{j < k} \frac{g_{jk}(N_i)}{g_{jk}}$$

In the above formula g_{jk} is the number of geodesic paths between the two nodes j and k (dyad) and $g_{jk}(N_i)$ is the number of geodesics between j and k that contain j .

Then dividing $g_{jk}(N_i)$ by g_{jk} measures the proportion of geodesic path connecting j and k in which node i is involved. Summing across all the dyads not including node i measure the extent to which i sits on the geodesic path of the other network members. Wasseman and Faust suggest normalizing the actor betweenness centrality by dividing it by the maximum theoretical value of $\frac{(g_{-1})(g_{-2})}{2}$ assuming each pair has only one geodesic according to the formula:

$$C'_B(N_i) = \frac{C_B(N_i) \times 2}{(g-1)(g-2)}$$

“The standardised actor betweenness centrality is 0.0 when the original betweenness centrality is 0 and it is 1.0 when node i falls on the geodesic path of every dyad of the remaining $g-1$ nodes. Therefore, the closer the standardised betweenness centrality is to 1.0 the more the actor controls or mediates relations in the network”³.

Closeness Centrality

The closeness centrality of an actor/node, developed by Sabidussi⁴, measures the extent to which a node/actor is close to all other actor/nodes in the network. It is based on the total distance between the node/actor and all other nodes/actors, where larger distances imply lower closeness centrality values. Closeness and distance refer to how quickly an actor/node can interact with others, for example by communicating directly or via few intermediaries; again the geodesic or the shortest path is a key concept and by distance is meant the number of links which connect two nodes and not the geographical distance.

In fact the closeness centrality (C_C) of an actor/node (N_i) is based on the geodesic to all other nodes “and is computed as the inverse of the sum of the geodesic distances between actor i and the $g-1$ other actors”⁵:

$$C_c(N_i) = \frac{C_c(N_i) \times 2}{(g-1)(g-2)}$$

Again, closeness centrality might vary with network size. Therefore, Beauchamp suggested that the index of actor closeness centrality should be standardised by multiplying it by the maximum of nodes in the network minus 1⁶:

$$C_c(N_i) = (g-1)(C_c(N_i))$$

Normalised Degree Centrality

The degree centrality measures “the extent to which a node connects to all other nodes in a social network” and indicates how easily information can reach a node. It is based on the assumption that more links and neighbours a node has, the higher the probability of that node to receive information and is given by the following equation⁷:

$$C_D(N_i) = \sum_{j=1}^g X_{ij} (i \neq j)$$

This means that in a simple and undirected network (where g is the total number of nodes or actors) the degree centrality (C_D) of an actor or node i (N_i) is given by the sum of the number of its direct links to the $g-1$ other j nodes of the networks that is, in simple term, the number of its neighbours⁸. Actor degree centrality, however, may vary with the size of the network (g or the number of nodes/actors). In fact, the larger the network, or the number of its nodes/actors, the higher the potential of each single node/actor to be directly linked to other nodes/actors. For example, an absolute degree centrality of 3 (which means direct links to three other actors), might represent a high value in a network of 5 nodes/actors but would be a very low value in a network of 50 or more nodes/actors.

Therefore, Wasserman and Faust, to eliminate the effect of variation in degree centrality caused by the size of the network (g) suggest it to be normalised according to the following formula⁹:

$$C'_D(N_i) = \frac{C_D(N_i)}{g - 1}$$

Then the normalised degree centrality (C'_D) of a node i (N_i) is given by its degree centrality ($C_D(N_i)$) divided by the maximum number of possible connections with other nodes/actors that is the total number of nodes (g) minus one, the node itself ($g - 1$). In this way it is possible to yield the “proportion of the network members with direct ties to actor i . Proportion varies between 0.0 indicating no connections with any actor (i.e. isolate), to 1.0 reflecting direct ties to everyone. Normalised degree centrality measures the extent to which an actor is involved in numerous relationships. Actors with high scores are the most visible participants in a network”¹⁰.

In the following pages the results of the calculation of the centrality indexes respectively on the fluvial and terrestrial routes network of southern Etruria and Latium vetus are presented. And also the calculation of the percentage of central places predicted both by size and by degree, calculated on the total of sites predicted to be central only by size. This will give an idea of how much the different centrality degree are instrumental to the

overall ‘centrality’ or ‘importance’ of the primary proto-urban centres, indicated by their size as a ‘proxy’.

Calculation of percentages of sites predicted to be central by centrality indexes and by size

Latium Vetus Fluvial Routes Networks: Betweenness Centrality

Threshold of Betweenness Centrality for Central Place based on observation trough different phases = 0.050.

(For data, please visit www.cambridge.org/fulminante/LatiumVetusFluvialRoutesNetworks_BetweennessCentrality)

Latium Vetus Fluvial Network: Closeness Centrality

Threshold of Closeness Centrality for Central Place based on observation trough different phases = 0.14-0.15 for the Final Bronze Age and the Early Iron Age 1 and 0.12-0.15 for the Early Iron Age 2, Orientalizing and Archaic Ages.

(For data, please visit www.cambridge.org/fulminante/LatiumVetusFluvialNetwork_ClosenessCentrality)

Latium Vetus Fluvial Network: Normalised Degree Centrality

Threshold of Normalised Degree Centrality for Central Place based on observation of values of primary settlements trough different phases = 0.04-0.05 for the Final Bronze age, but 0.02-0.05 for the Early Iron Age and later periods, except the Archaic Age when it is 0.04-0.05 again.

(For data, please visit www.cambridge.org/fulminante/LatiumVetusFluvialNetwork_NormDegCentrality)

Latium Vetus Terrestrial Routes Network: Betweenness Centrality

Threshold of Betweenness Centrality for Central Place based on observation trough different phases = 0.050.

(For data, please visit www.cambridge.org/fulminante/LatiumVetusTerrestrialRoutesNetwork_betweennesscentrality)

Latium Vetus Terrestrial Routes Network: Closeness Centrality

Threshold of Closeness Centrality for Central Place based on observation trough different phases = 0.24-0.25 and 0.22-0.23 for the Final Bronze Age.

(For data, please visit www.cambridge.org/LatiumVetusTerrestrialRoutesNetwork_ClosenessCentrality)

Latium Vetus Terrestrial Network: Normalised Degree Centrality

Threshold of Normalised Degree Centrality for Central Place based on observation trough different phases = 0.04-0.05

(For data, please visit www.cambridge.org/fulminante/LatiumVetusTerrestrialNetwork_NormalizedDegreeCentrality)

Etruria Fluvial Routes Network: Betweenness Centrality

Threshold of Betweenness Centrality for Central Place based on observation trough different phases= 0.050.

(For data, please visit www.cambridge.org/fulminante/EtruriaFluvialRoutesNetwork_BetweennessCentrality)

Etruria Fluvial Routes Network: Closeness Centrality

Threshold of Closeness Centrality for Central Place based on observation trough different phases = 0.07-0.08

(For data, please visit www.cambridge.org/fulminante/EtruriaFluvialRoutesNetwork_ClosenessCentrality)

Etruria Fluvial Routes Network: Normalised Degree Centrality

Threshold of Normalised Degree Centrality for Central Place based on observation trough different phases = 0.02-0.03 for the Final Bronze Age, the Orientalising and Archaic Age and 0.03-0.05 for the Early Iron Age.

(For data, please visit www.cambridge.org/fulminante/EtruriaFluvialRoutesNetwork_NormalizedDegreeCentrality)

Etruria Terrestrial Routes Network: Betweenness Centrality

Threshold of Betweenness Centrality for Central Place based on observation trough different phases = 0.050

(For data, please visit www.cambridge.org/fulminante/EtruriaTerrestrialRoutesNetwork_BetweennessCentrality)

Etruria Terrestrial Routes Networks: Closeness Centrality

Threshold of Closeness Centrality for Central Place based on observation trough different phases = 0.18-0.20

(For data, please visit www.cambridge.org/fulminante/EtruriaTerrestrialRoutesNetworks_ClosenessCentrality)

Etruria Terrestrial Network: Normalised Degree Centrality

Threshold of Normalised Degree Centrality for Central Place based on observation trough different phases = 0.04-0.05 for the Early Iron Age and 0.03-0.04 for the Orientalizing and Archaic Age

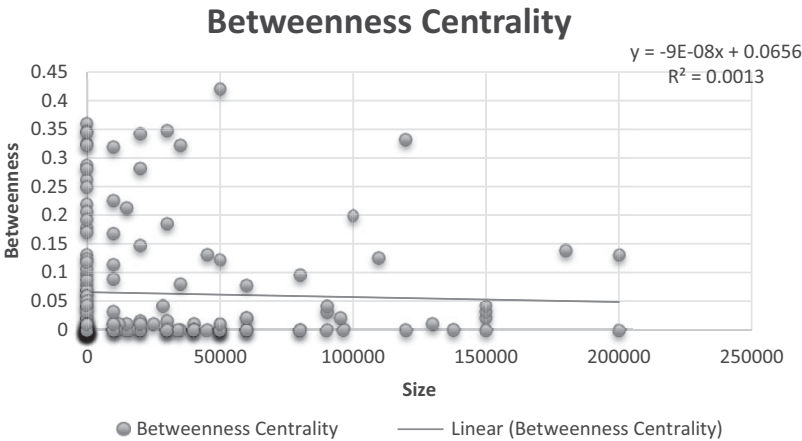
(For data, please visit www.cambridge.org/fulminante/EtruriaTerrestrialNetwork_NormalizedDegreeCentrality)

Correlation between settlement size and their centrality measures

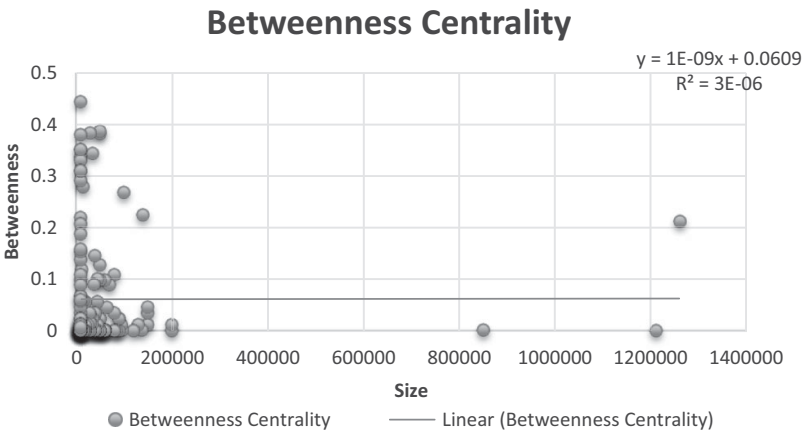
Etruria

Betweenness Centrality Rivers

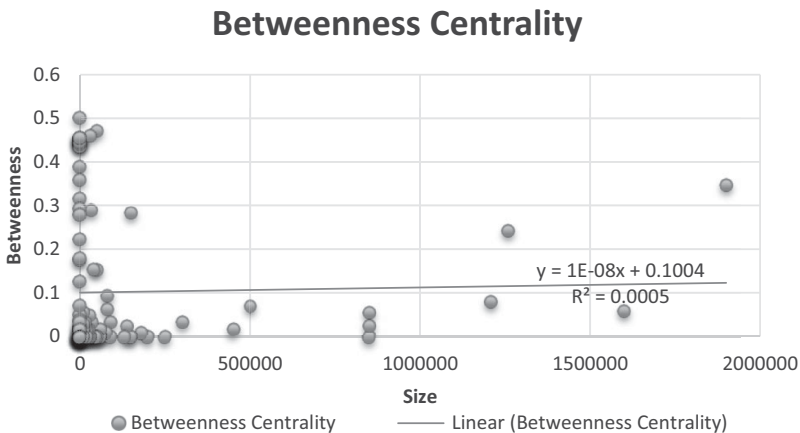
Final Bronze Age 1-2 Etruria



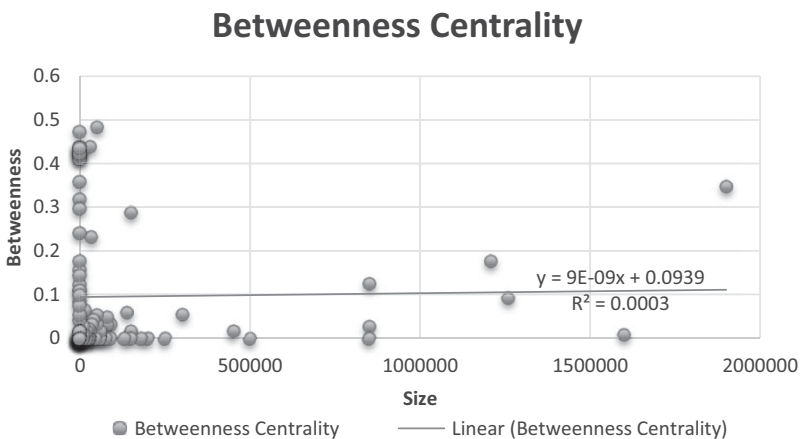
Final Bronze Age 3 Etruria



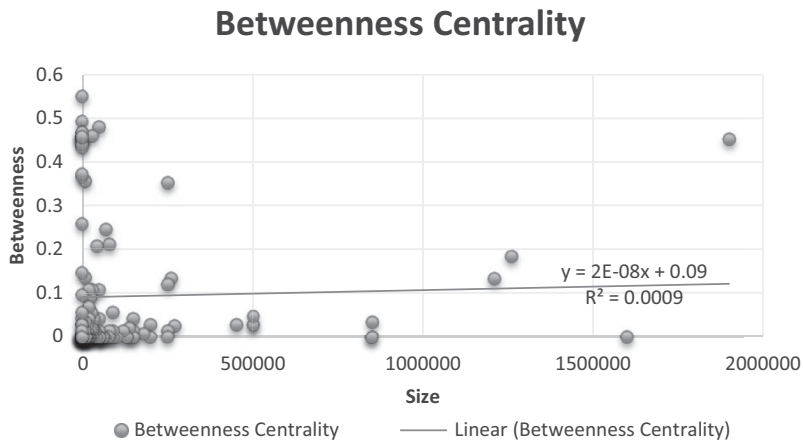
Early Iron Age 1 Early Etruria



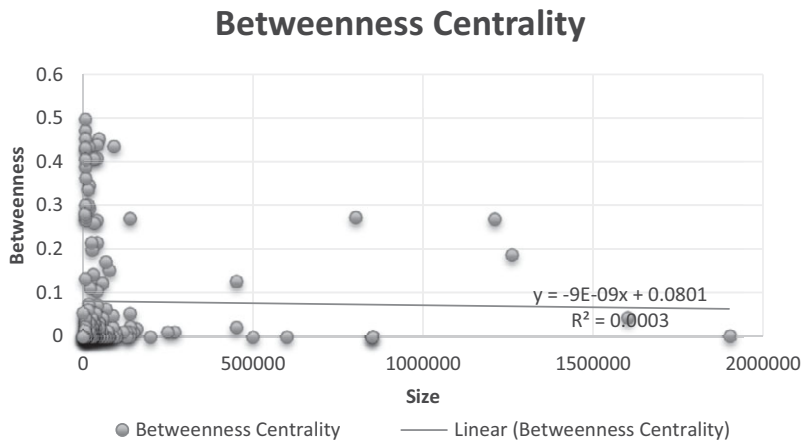
Early Iron Age 1 Late Etruria



Early Iron Age 2 Etruria

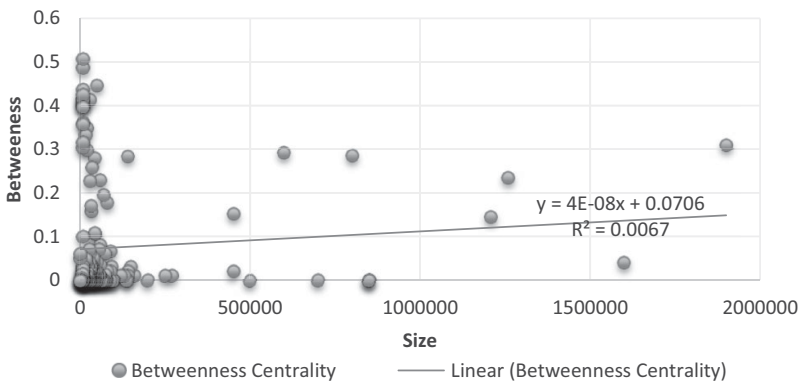


Orientalizing Age Etruria



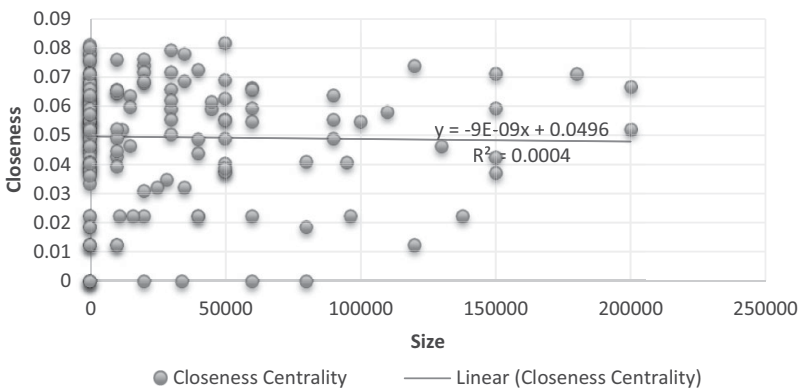
Archaic Age Etruria

Betweenness Centrality

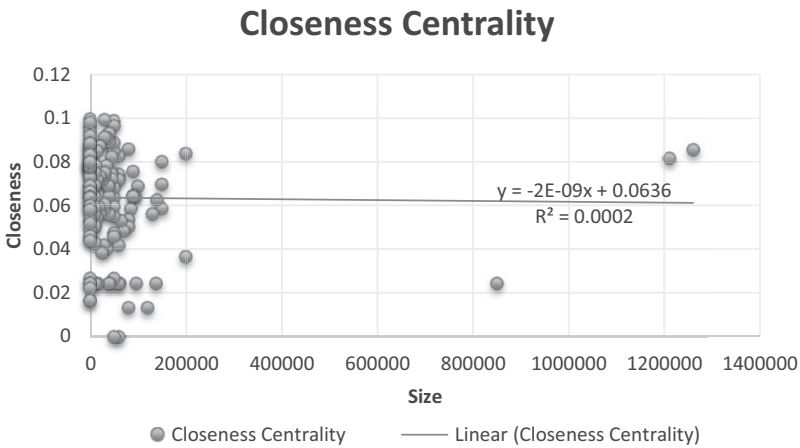


Closeness Centrality Rivers
Final Bronze Age 1-2 Etruria

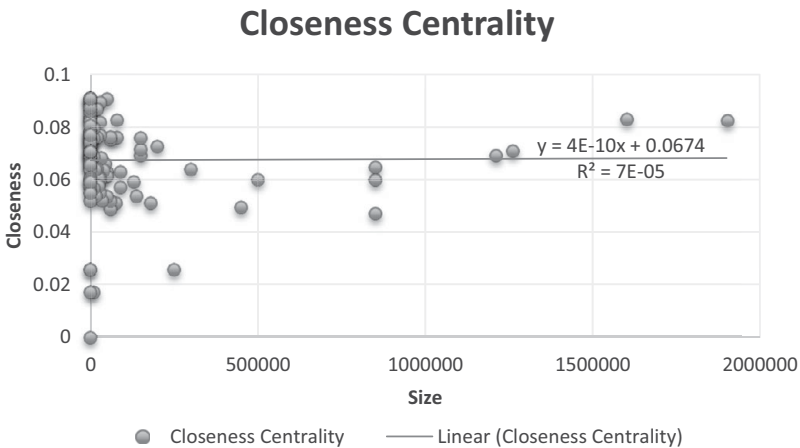
Closeness Centrality



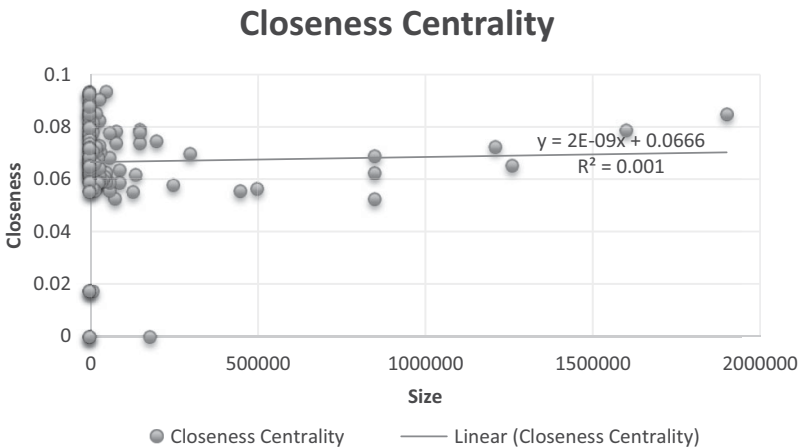
Final Bronze Age 3 Etruria



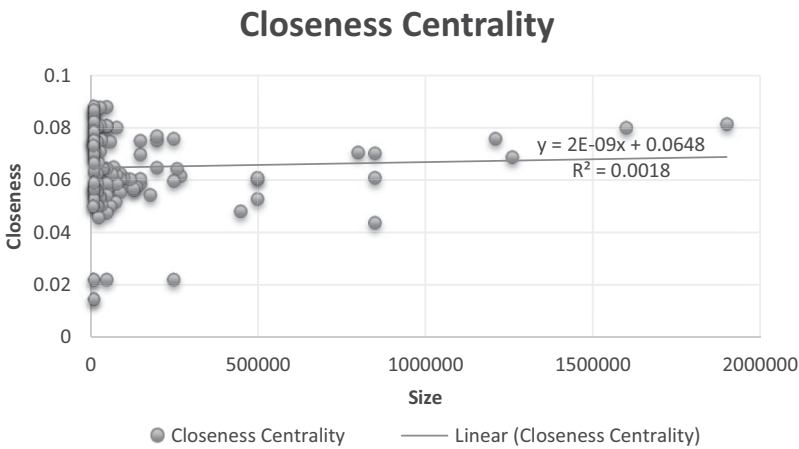
Early Iron Age 1 Early Etruria



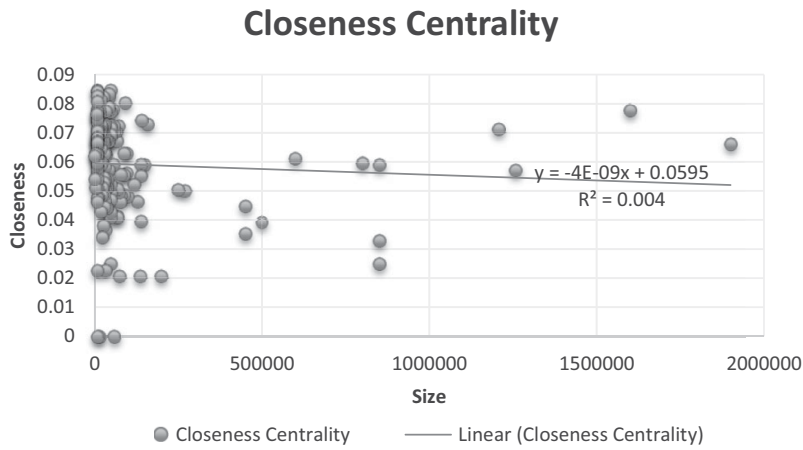
Early Iron Age 1 Late Etruria



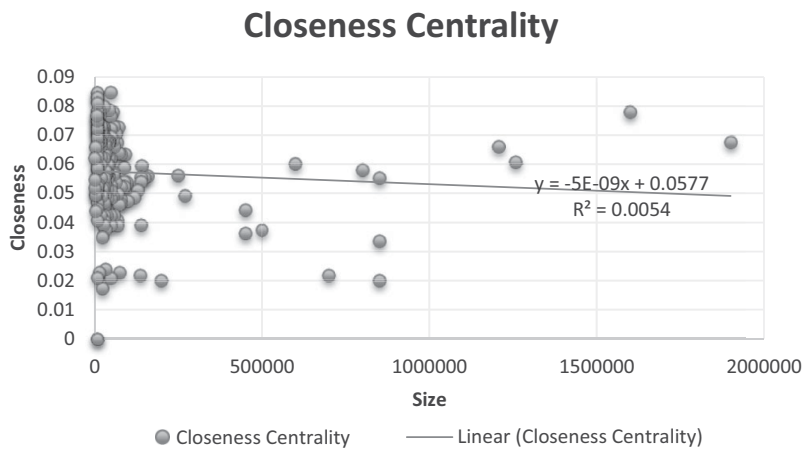
Early Iron Age 2 Etruria



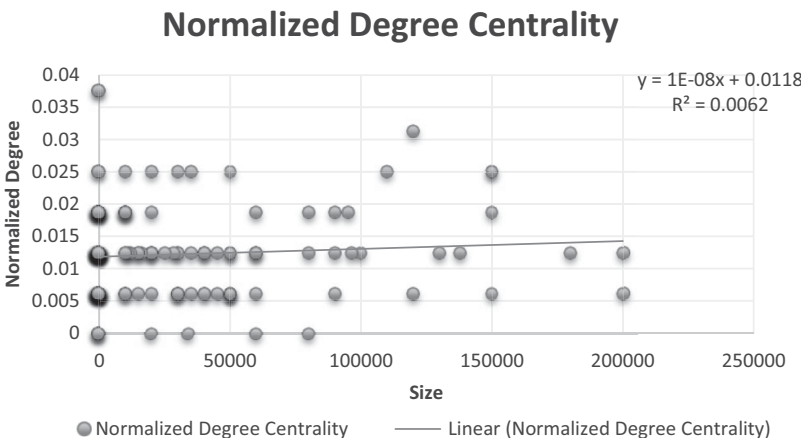
Orientalizing Age Etruria



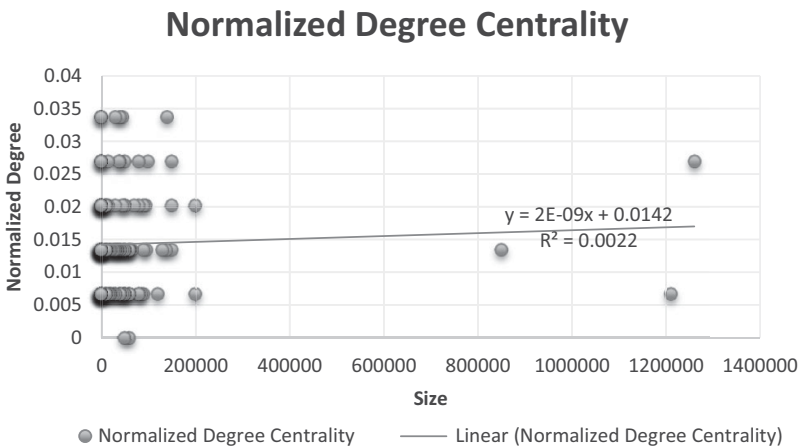
Archaic Age Etruria



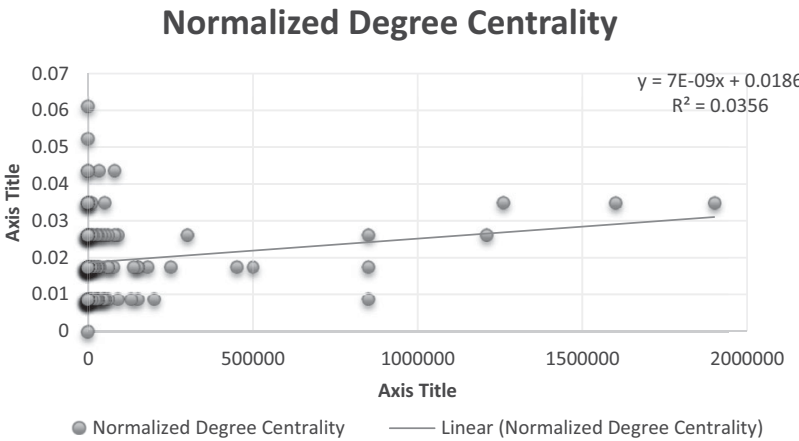
Normalised Degree Centrality Rivers
Final Bronze Age 1-2 Etruria



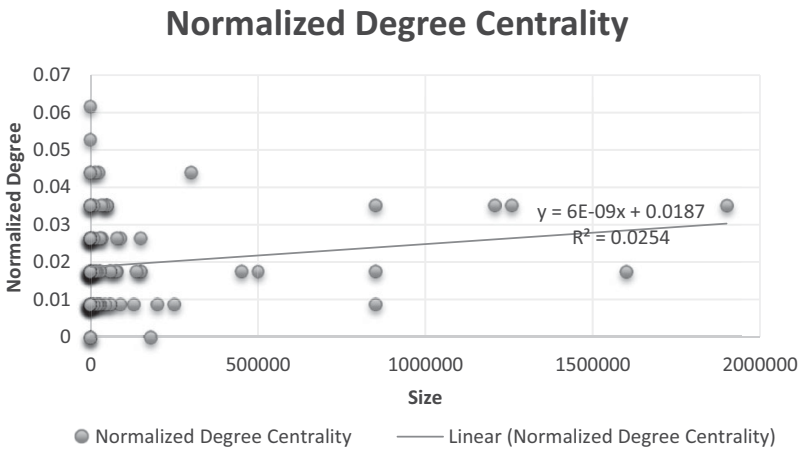
Final Bronze Age 3 Etruria



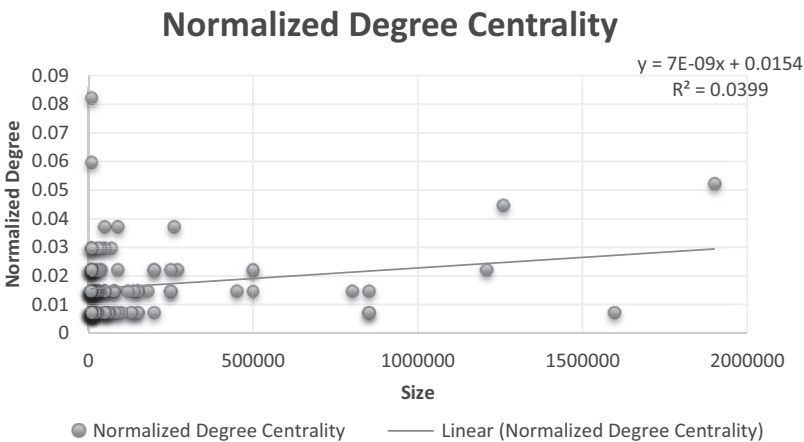
Early Iron Age 1 Early Etruria



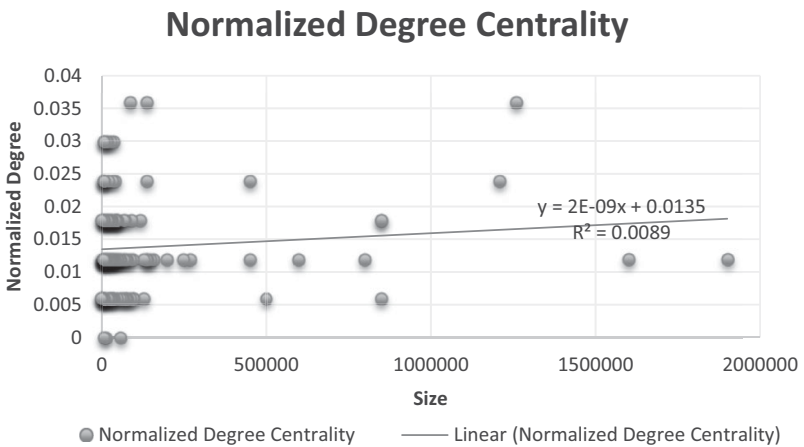
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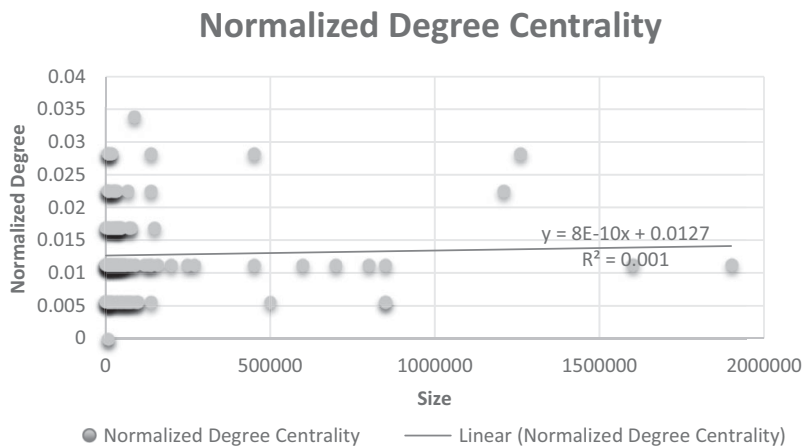
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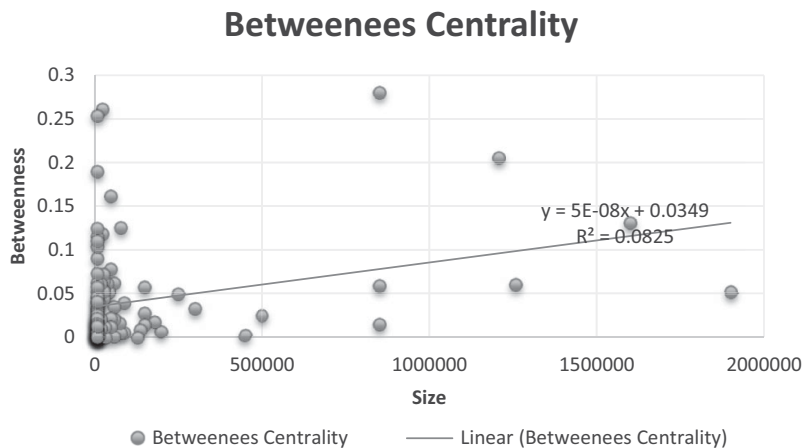
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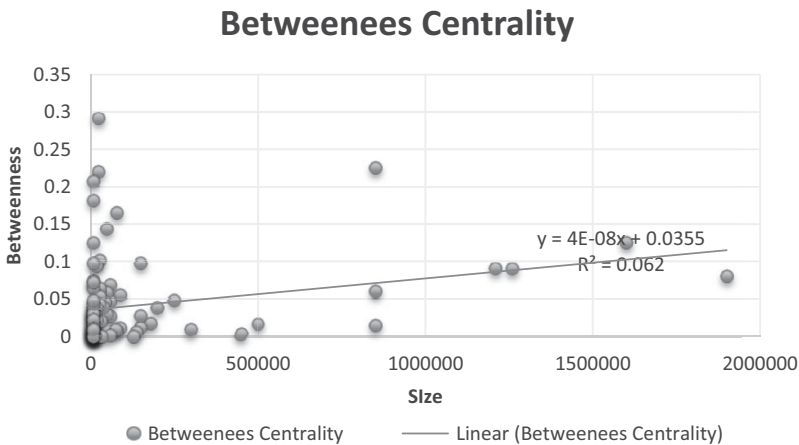
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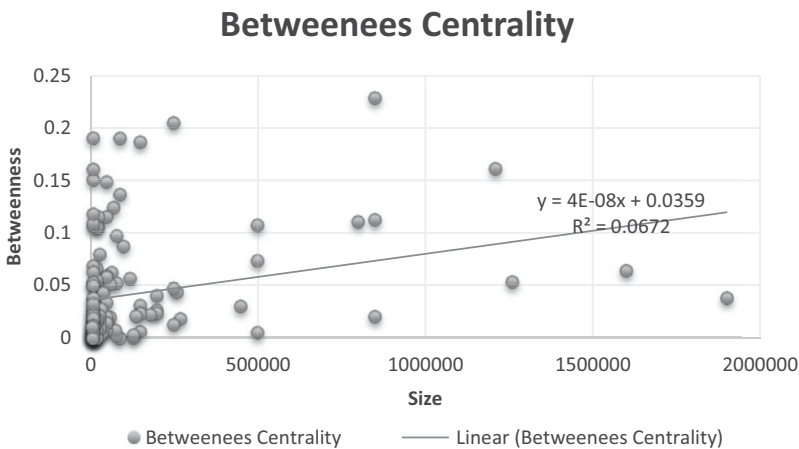
Betweenness Centrality Terrestrial Routes
Early Iron Age 1 Early Etruria



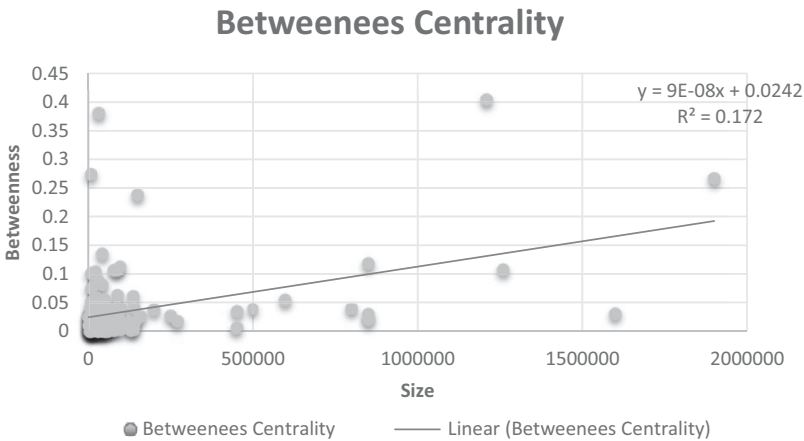
Early Iron Age 1 Late Etruria



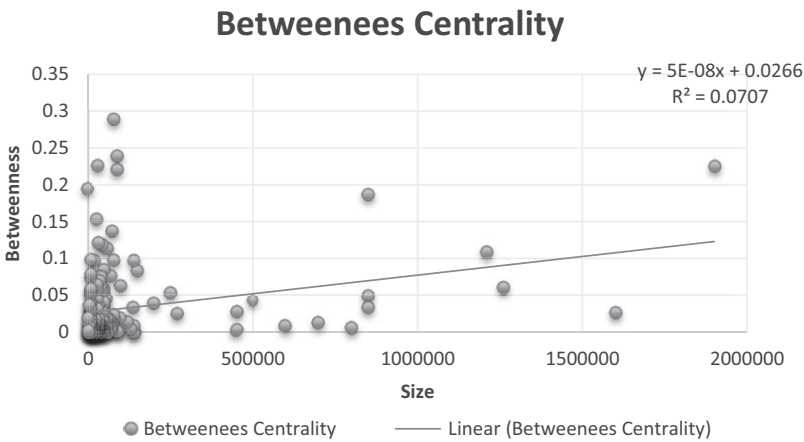
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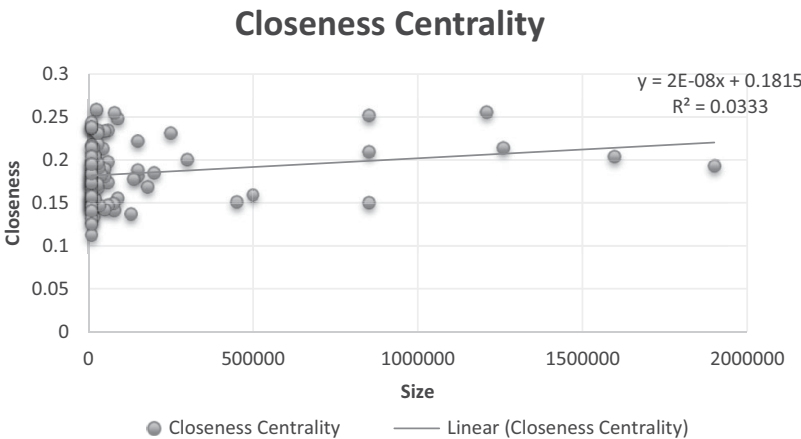
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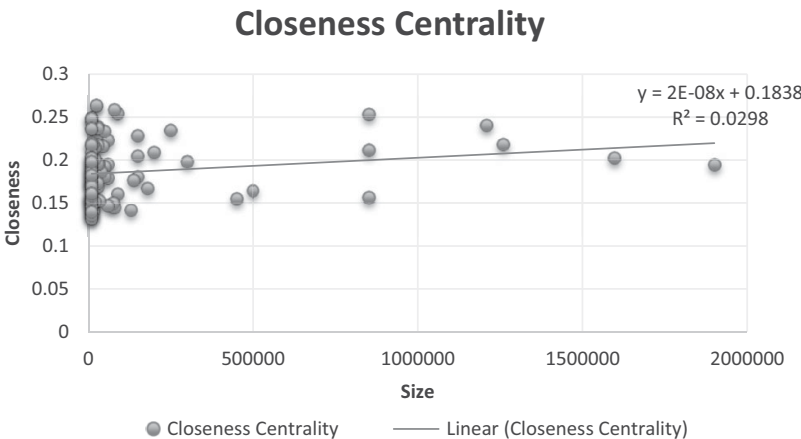
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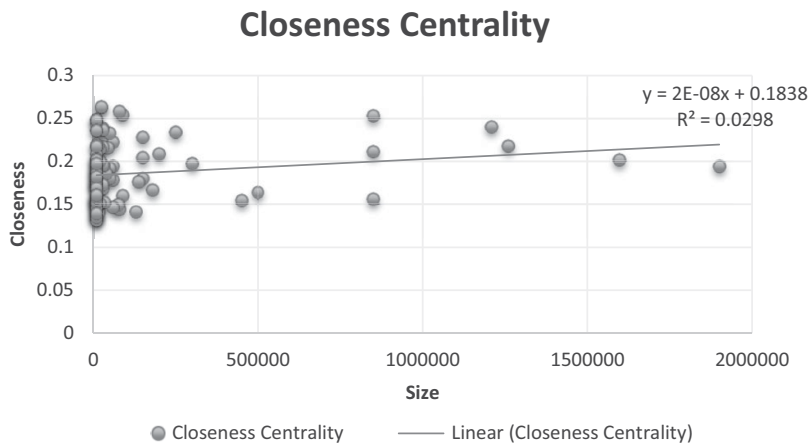
Closeness Centrality Terrestrial Routes
Early Iron Age 1 Early Etruria



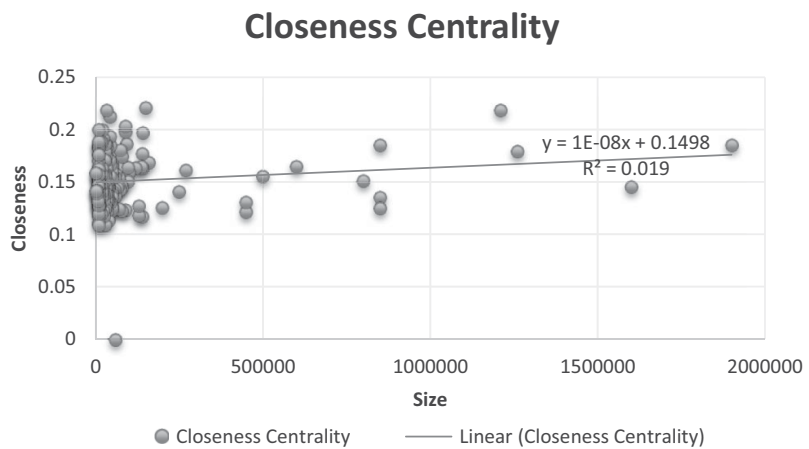
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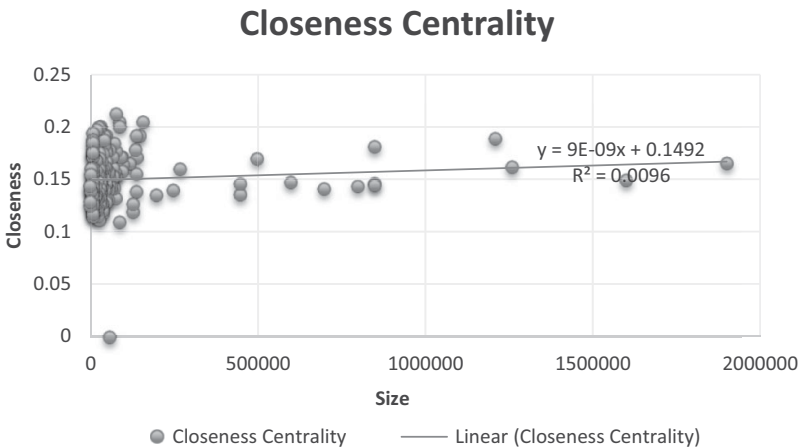
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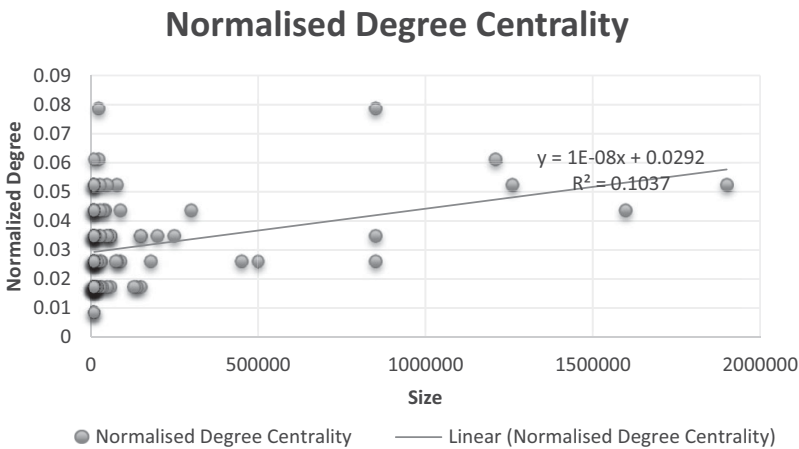
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Archaic Age Etruria

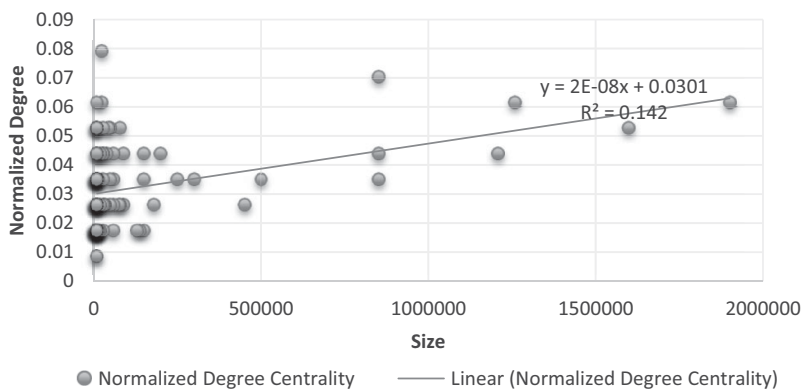


Normalised Degree Centrality Terrestrial Routes
Early Iron Age 1 Early Etruria



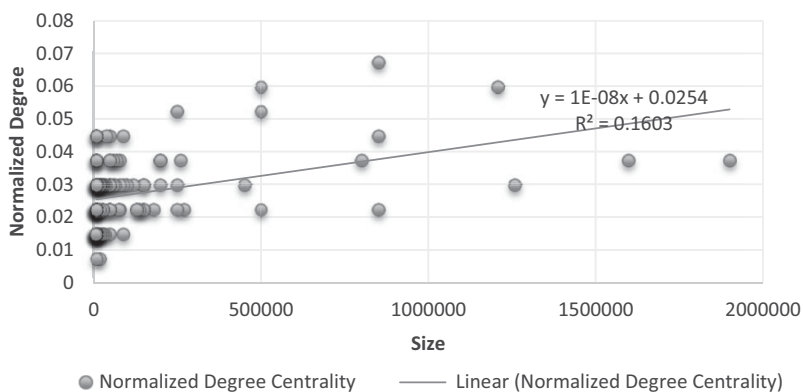
Early Iron Age 1 Late Etruria

Normalized Degree Centrality



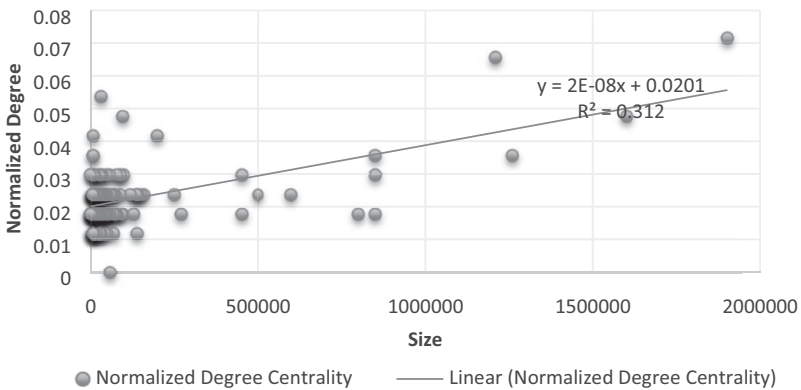
Early Iron Age 2 Etruria

Normalized Degree Centrality



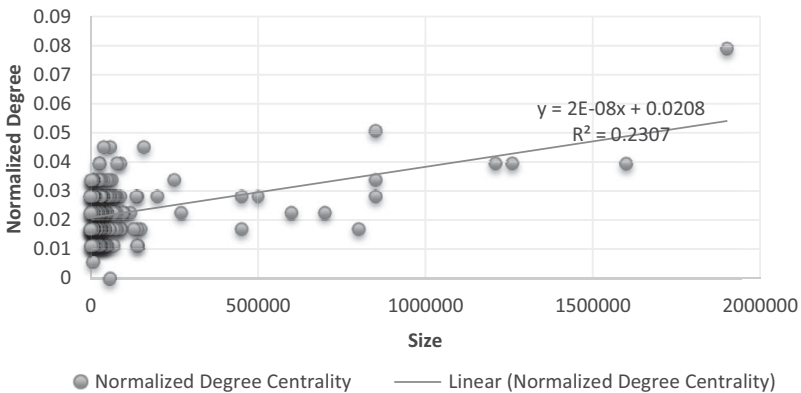
Orientalizing Age Etruria

Normalized Degree Centrality

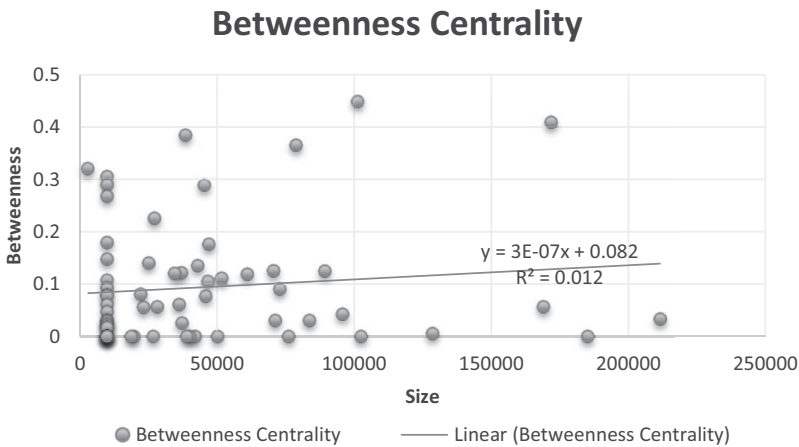


Archaic Age Etruria

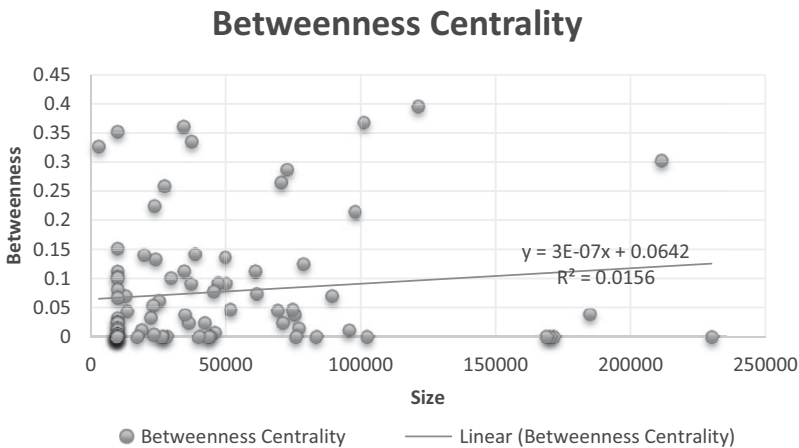
Normalized Degree Centrality



Latium
Betweenness Centrality Rivers
Final Bronze Age 1-2 Latium

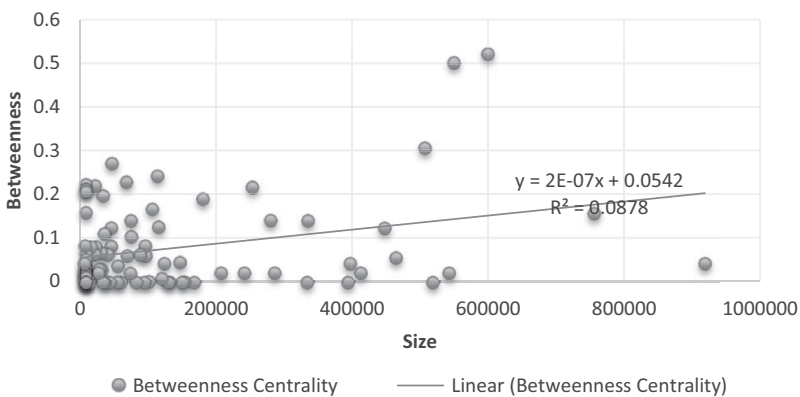


Final Bronze Age 3 Latium



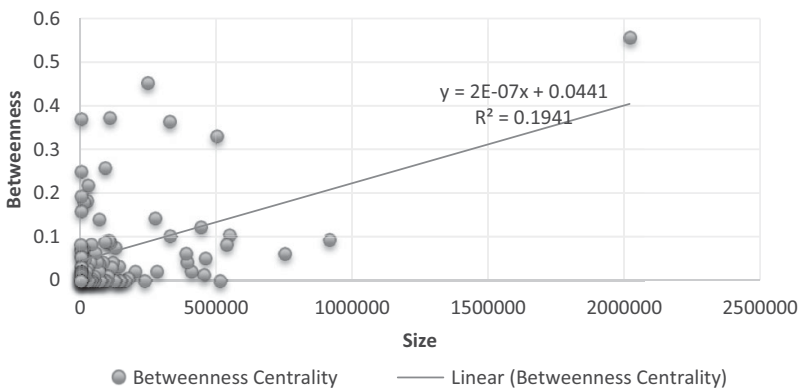
Early Iron Age 1 Early Latium

Betweenness Centrality

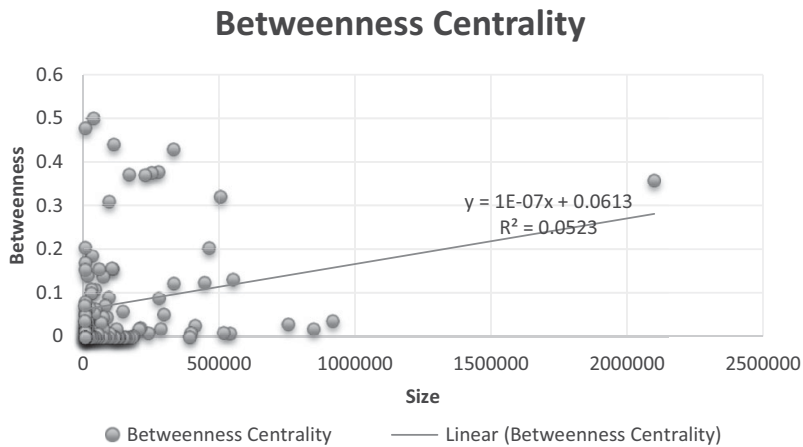


Early Iron Age 1 Late Latium

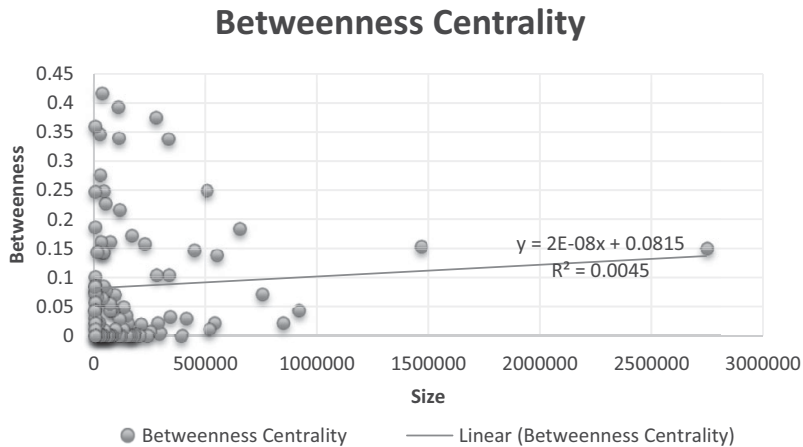
Betweenness Centrality



Early Iron Age 2 Latium

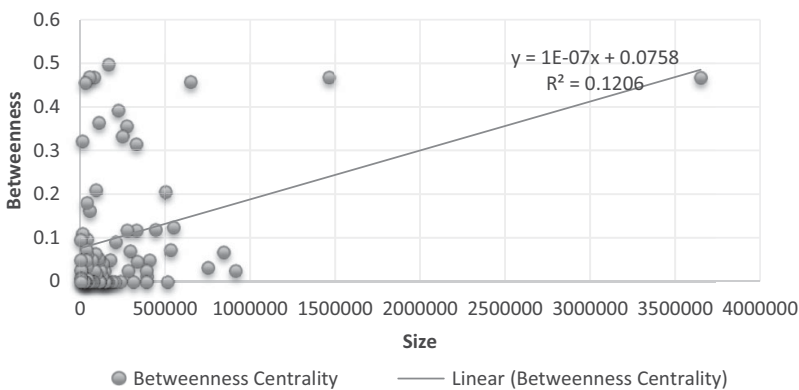


Orientalizing Age Latium



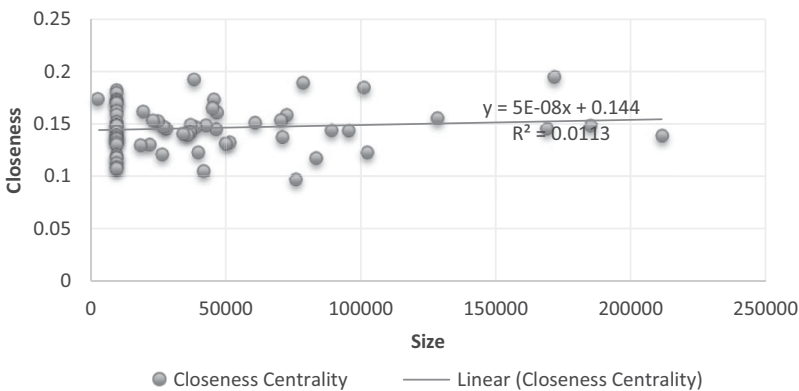
Archaic Age Latium

Betweenness Centrality

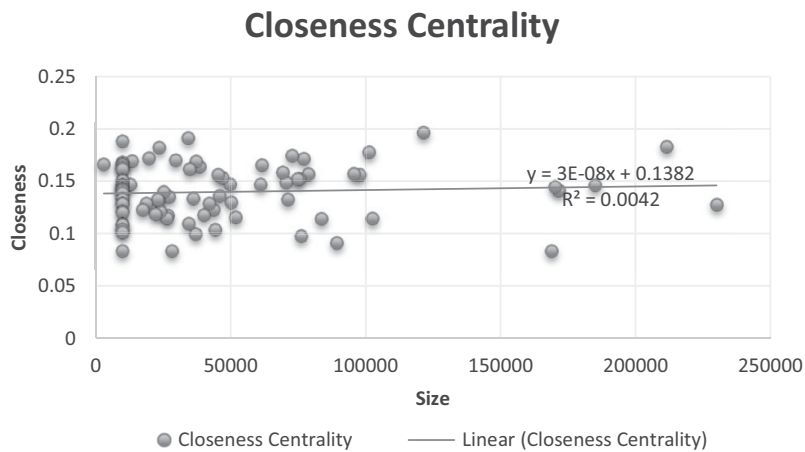


Closeness Centrality Rivers
Final Bronze Age 1-2 Latium

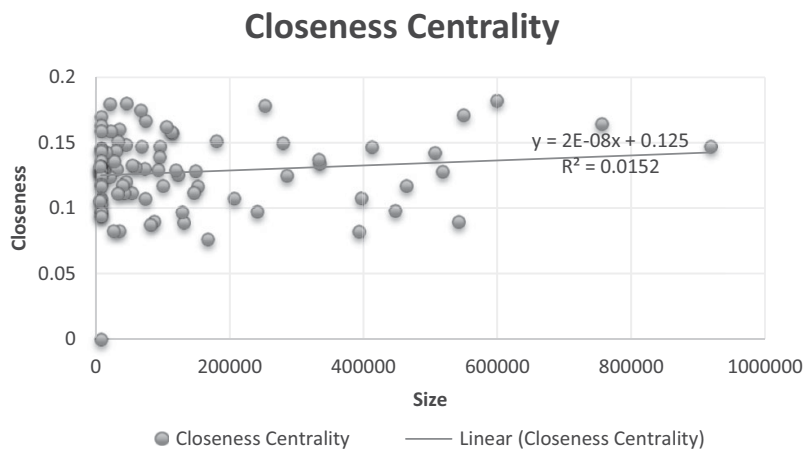
Closeness Centrality



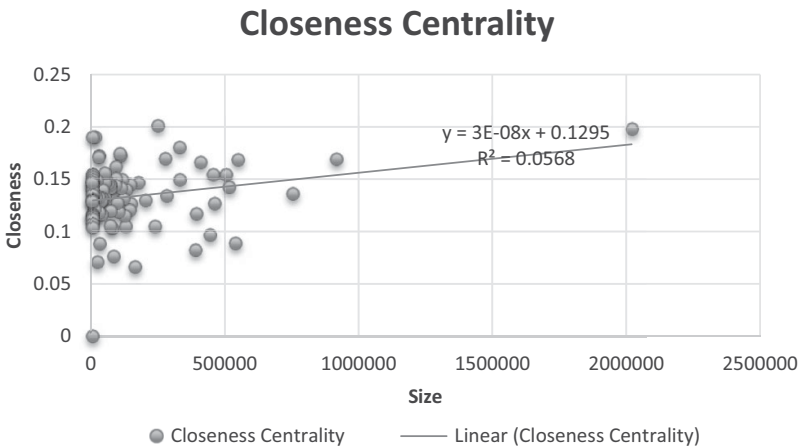
Final Bronze Age 3 Latium



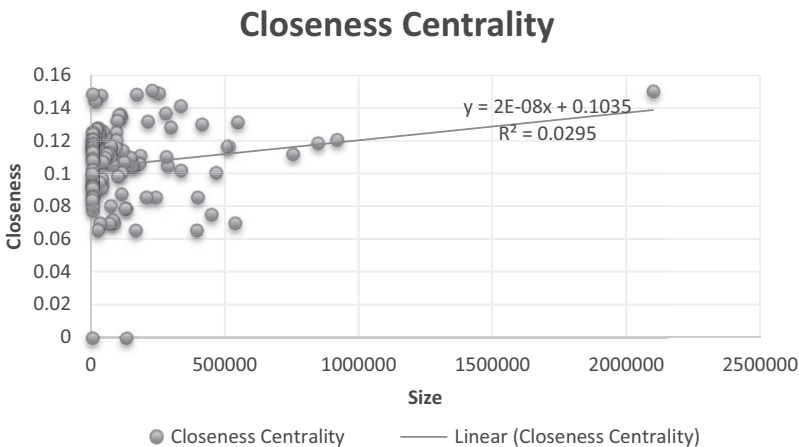
Early Iron Age 1 Early Latium



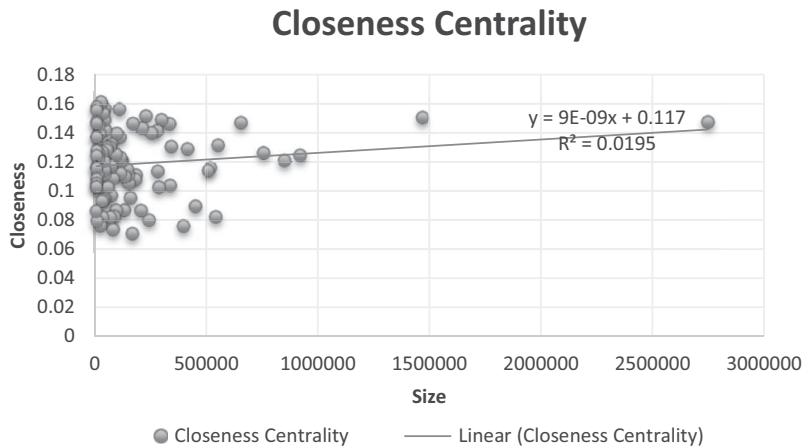
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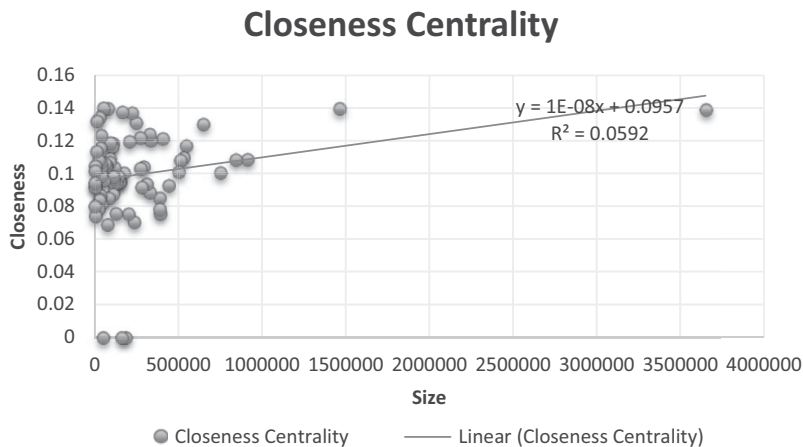
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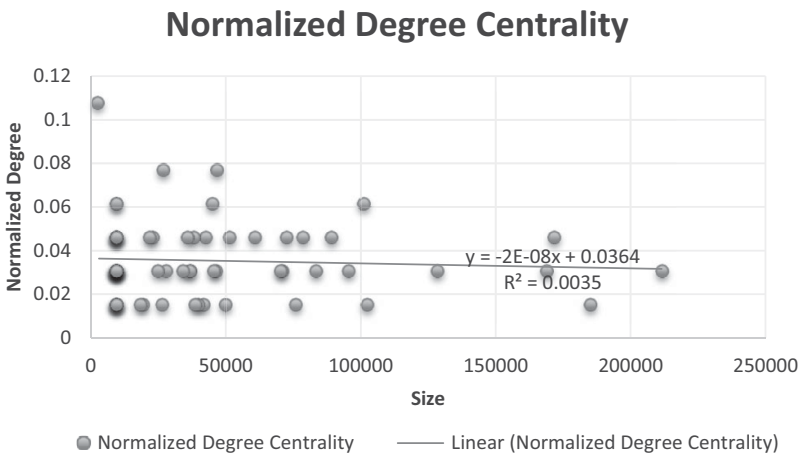
Orientalizing Age Latium



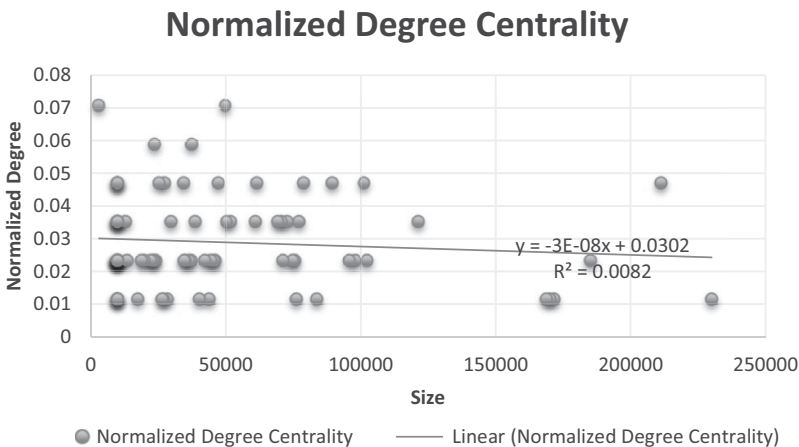
Archaic Age Latium



Normalised Degree Centrality Rivers
Final Bronze Age 1-2 Latium

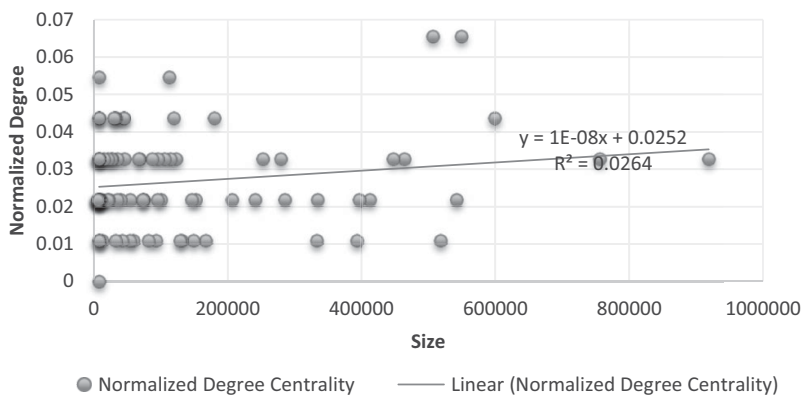


Final Bronze Age 3 Latium



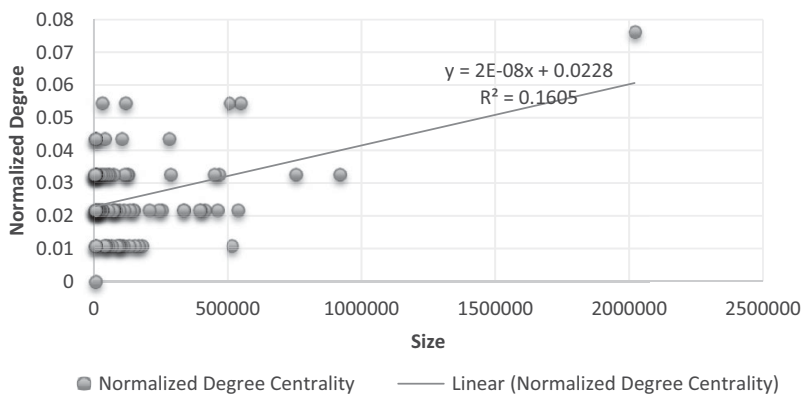
Early Iron Age 1 Early Latium

Normalized Degree Centrality



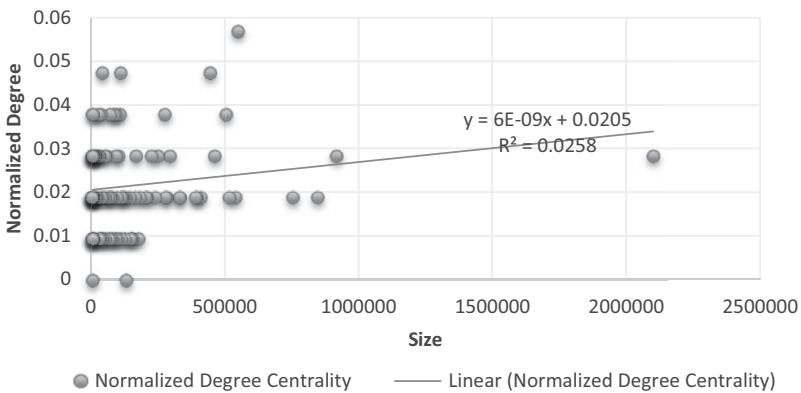
Early Iron Age 1 Late Latium

Normalized Degree Centrality



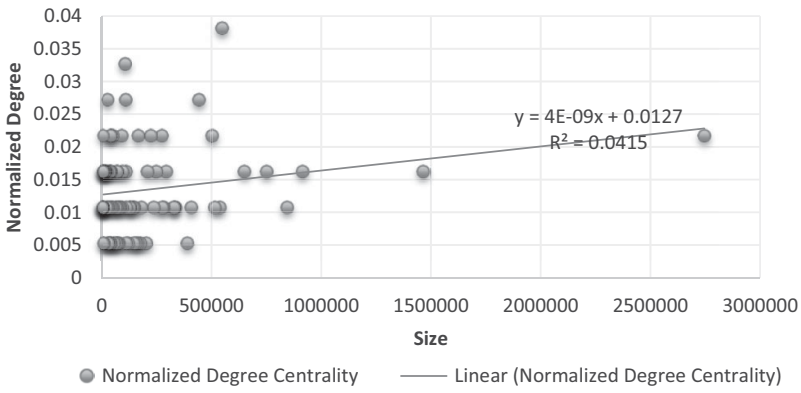
Early Iron Age 2 Latium

Normalized Degree Centrality



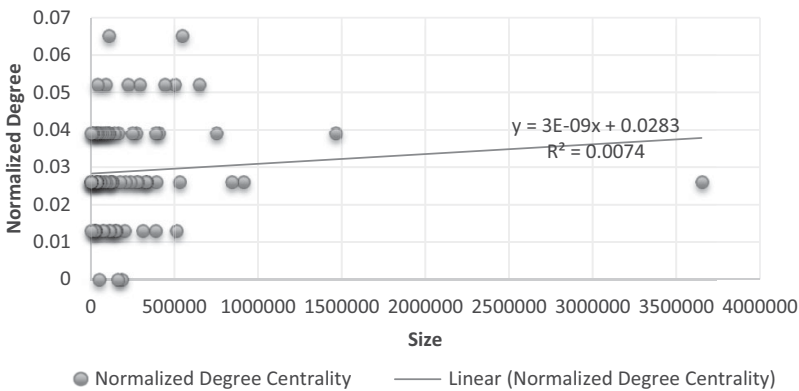
Orientalizing Age Latium

Normalized Degree Centrality



Archaic Age Latium

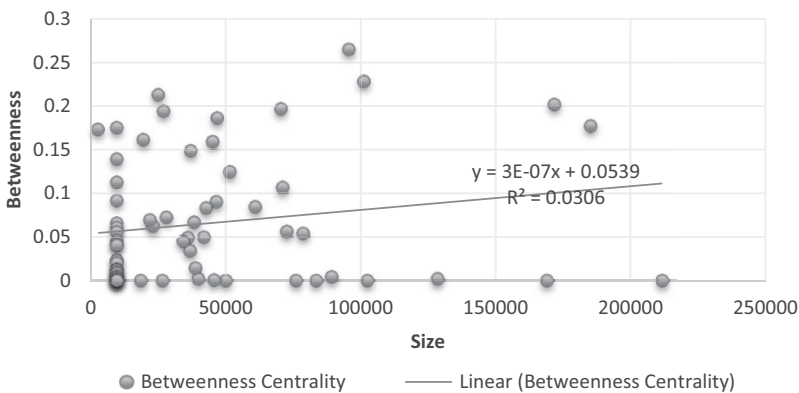
Normalized Degree Centrality



Betweenness Centrality Terrestrial Routes

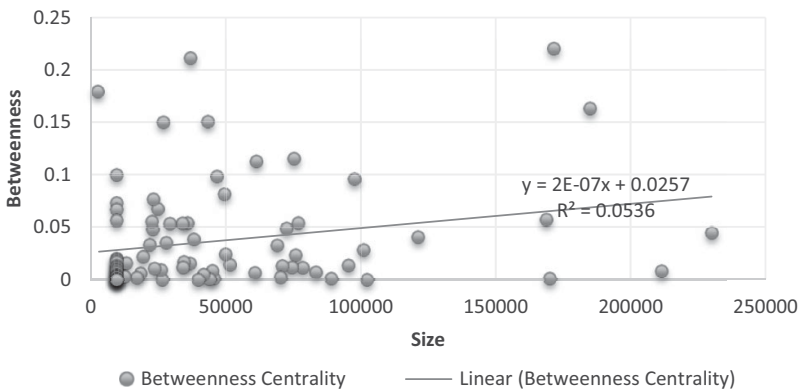
Final Bronze Age 1-2 Latium

Betweenness Centrality



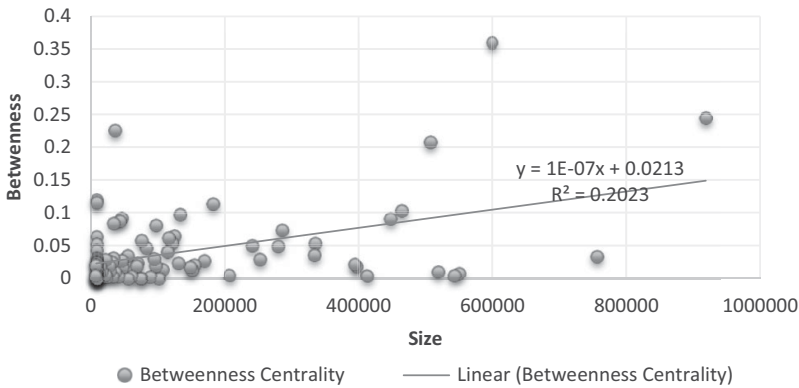
Final Bronze Age 3 Latium

Betweenness Centrality

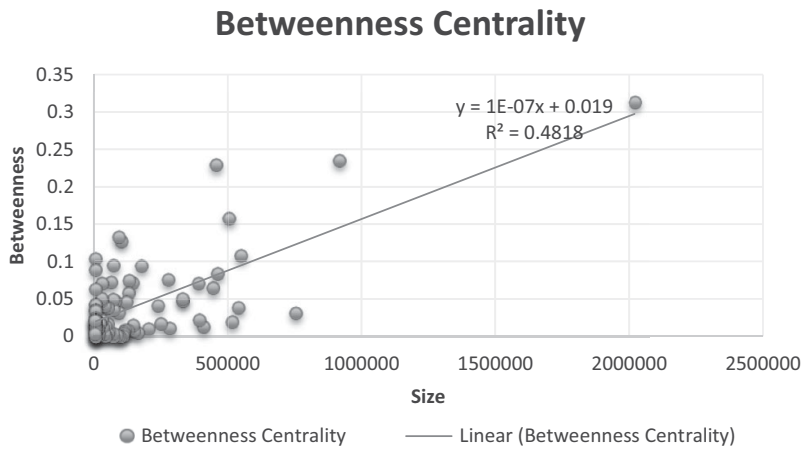


Early Iron Age 1 Early Latium

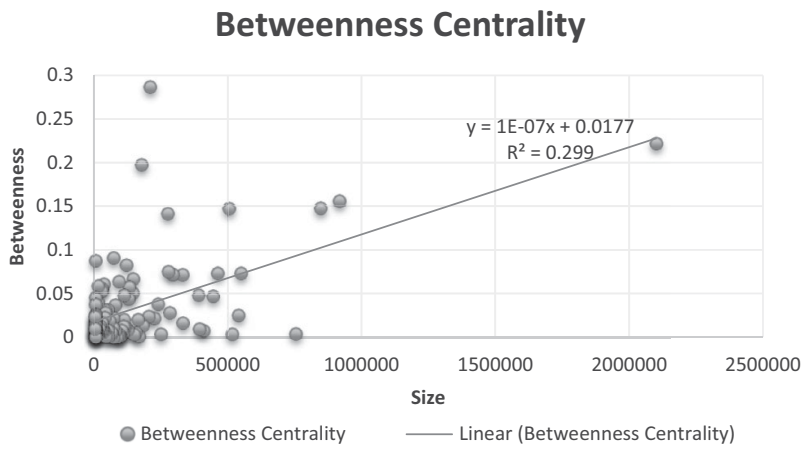
Betweenness Centrality



Early Iron Age 1 Late Latium

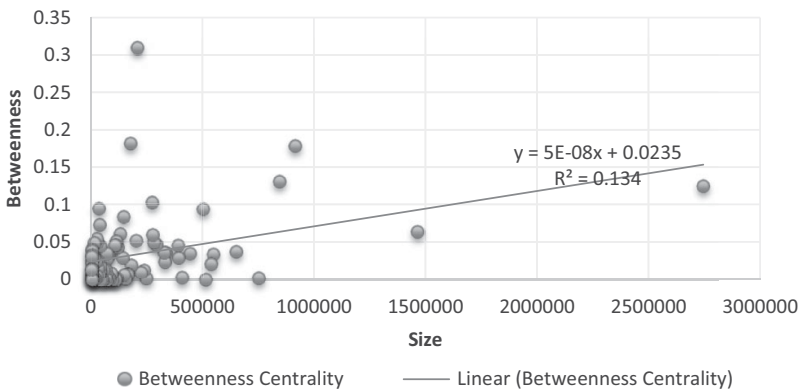


Early Iron Age 2 Latium



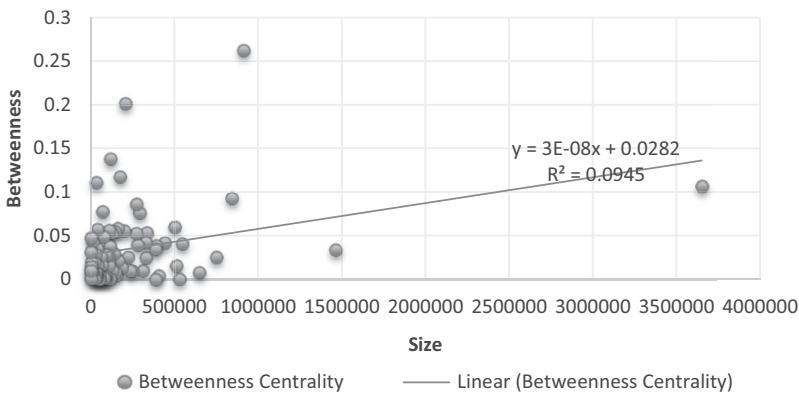
Orientalizing Age Latium

Betweenness Centrality

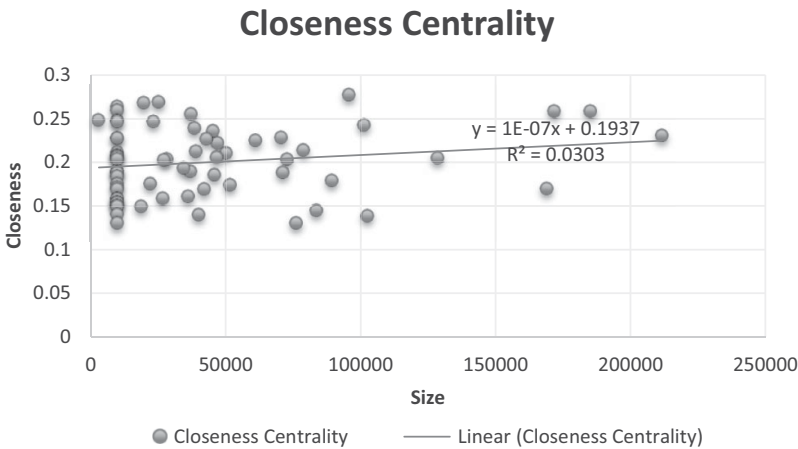


Archaic Age Latium

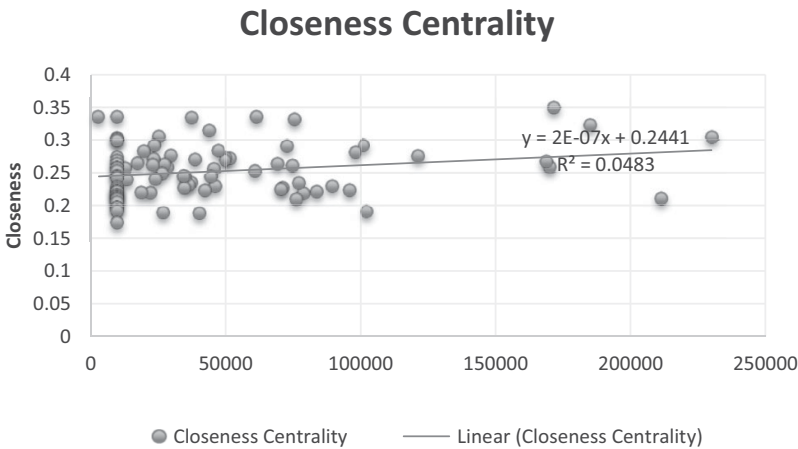
Betweenness Centrality



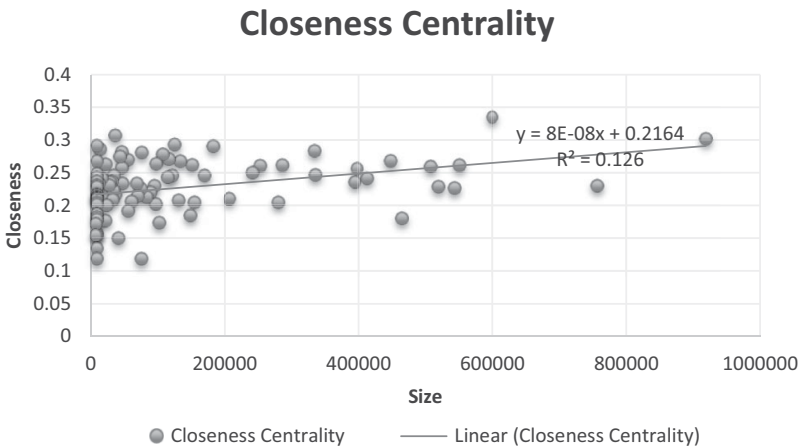
Closeness Centrality Terrestrial Routes
Final Bronze Age 1-2 Latium



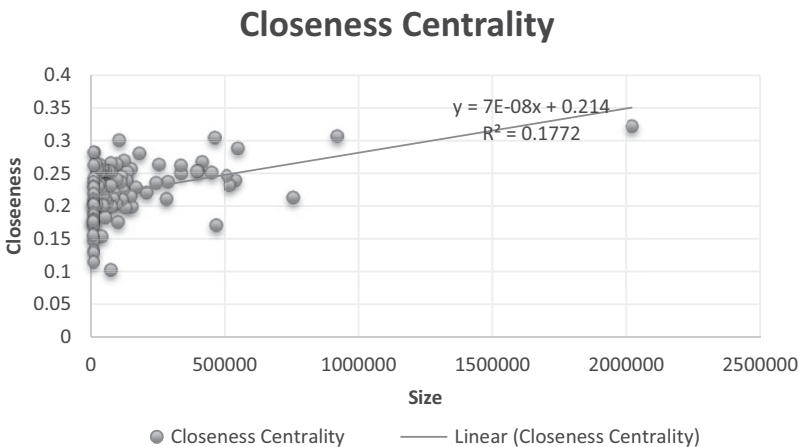
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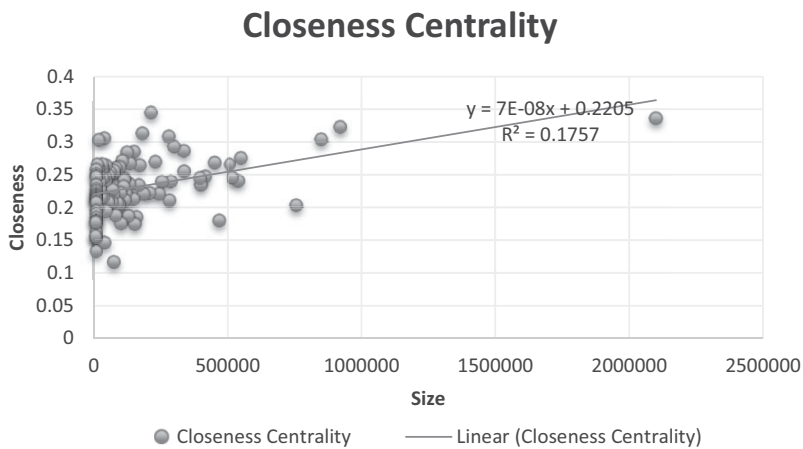
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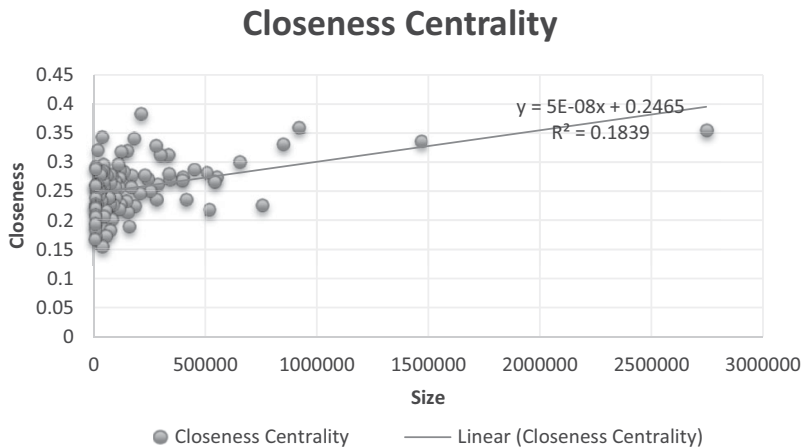
Early Iron Age 1 Late Latium



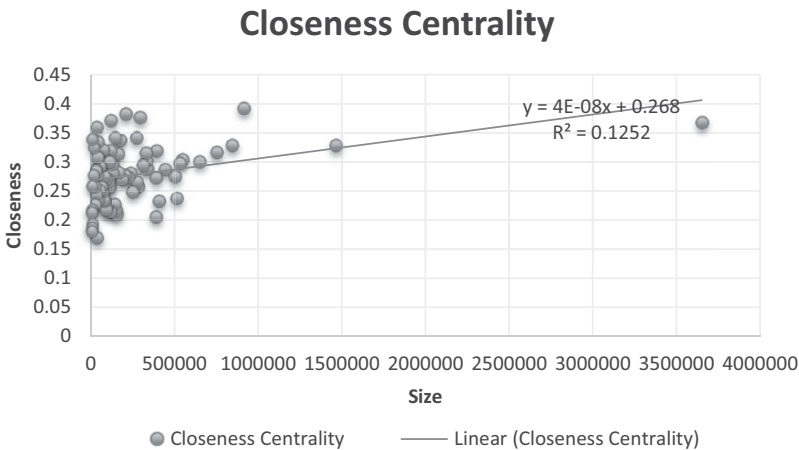
Early Iron Age 2 Latium



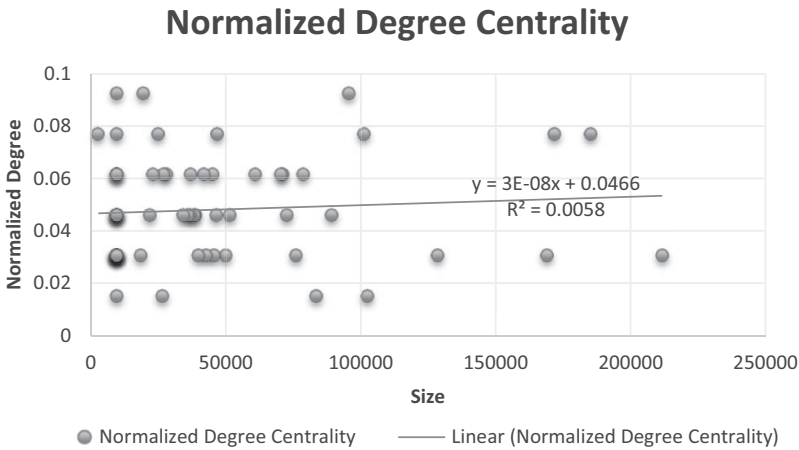
Orientalizing Age Latium



Archaic Age Latium

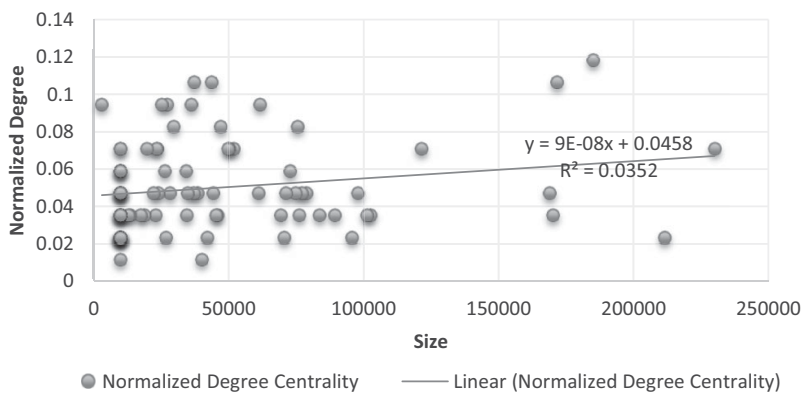


Normalised Degree Centrality Terrestrial Routes
Final Bronze Age 1-2 Latium



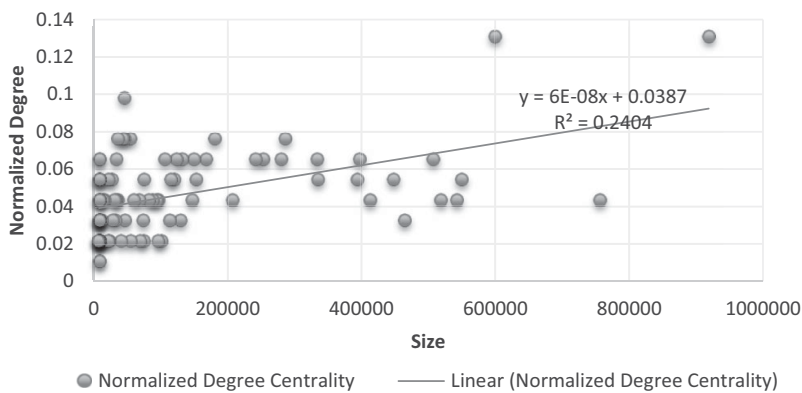
Final Bronze Age 3 Latium

Normalized Degree Centrality



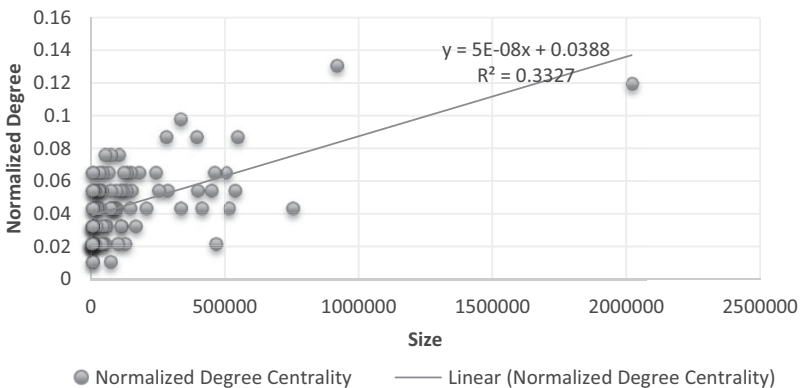
Early Iron Age 1 Early Latium

Normalized Degree Centrality



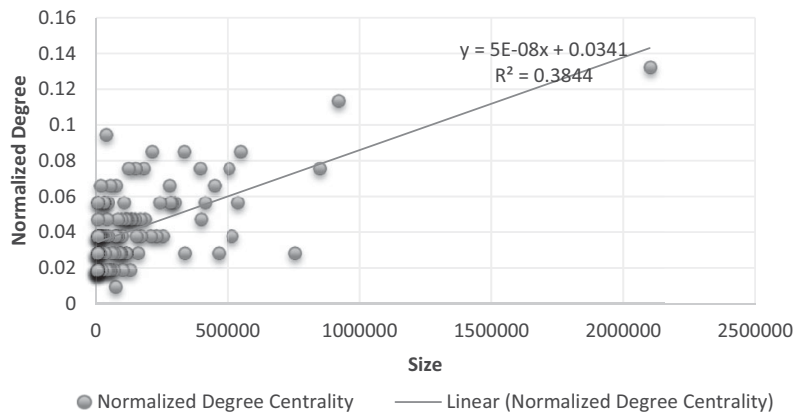
Early Iron Age 1 Late Latium

Normalized Degree Centrality



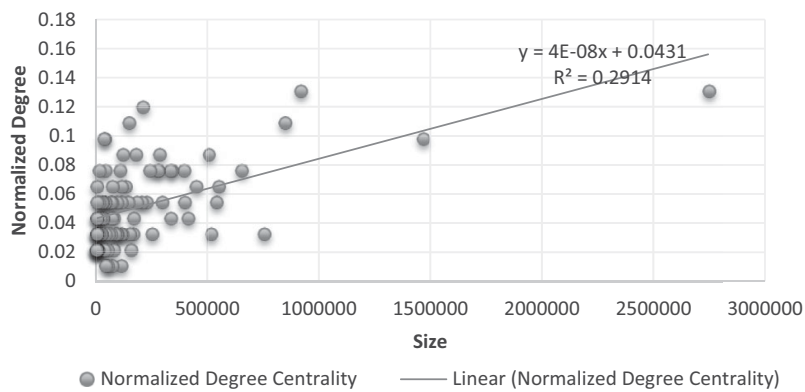
Early Iron Age 2 Latium

Normalized Degree Centrality



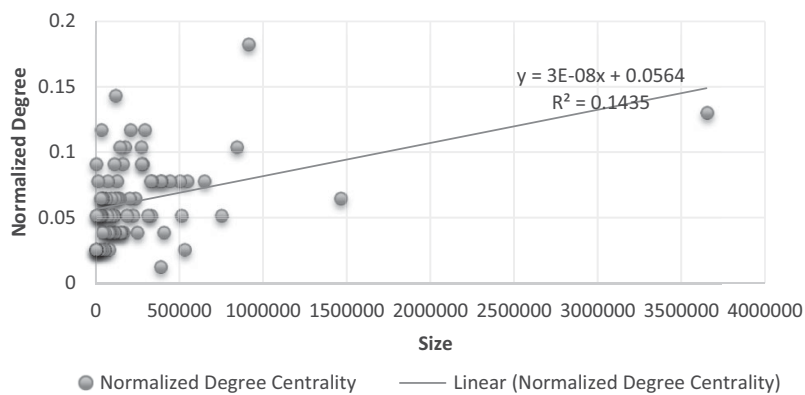
Orientalizing Age Latium

Normalized Degree Centrality



Archaic Age Latium

Normalized Degree Centrality



Confusion Matrix

Admittedly the methodology adopted above, implied the comparison of two variables, that have been partially determined and influenced by each other. Therefore, in this revised application I have applied also a more robust predicting method which is the ‘prediction or confusion matrix’. In this way it has been possible to verify which centres predicted to be central by their size where also predicted to be central by their degree centrality.

The confusion matrix is a popular representation of the performance of classification models. The matrix (table) shows us the number of correctly and incorrectly classified examples, compared to the actual outcomes (target value) in the test data. One of the advantages of using confusion matrix as evaluation tool is that it allows more detailed analysis (such as if the model is confusing two classes), than simple proportion of correctly classified examples (accuracy) which can give misleading results if the dataset is unbalanced (i.e. when there are huge differences in number of between difference classes).

The ‘prediction or confusion matrix’ tests predictions and correlation in complex matrices with the use of a logic table that cross-tabulates predicted and observed examples in four options: True Positive (TP): Correctly predicting a label (we predicted “yes”, and it’s “yes”).

True Negative (TN): Correctly predicting the other label (we predicted “no”, and it’s “no”).

False Positive (FP): Falsely Predicting a label (we predicted “yes”, but it’s “no”).

False Negative (FN): Missing and incoming label (we predicted “no”, but it’s “yes”).

A series of measures, illustrated below, allow to evaluate the performance of the model. We are particularly interested in the **precision**, which indicates the positive predictive value, the **false positive rate** and the **false discovery rate**, and the **accuracy**. These measures are illustrated in graphs and discussed in the text of Chapter 4.

Measure	Defitnition	Derivations
Sensitivity	True Positive Rate (TPR)	$TPR = TP / (TP + FN)$
Specificity	Specificity (SPC) or True Negative Rate (TNR)	$SPC = TN / (FP + TN)$

(cont.)

Measure	Defintition	Derivations
Precision	Positive Predictive Value (PPV)	$PPV = TP / (TP + FP)$
Negative Predictive Value	Negative Predictive Value (NPV)	$NPV = TN / (TN + FN)$
False Positive Rate	Fall-out or False Positive Rate (FPR)	$FPR = FP / (FP + TN)$
False Discovery Rate	False Discovery Rate (FDR)	$FDR = FP / (FP + TP)$
False Negative Rate	Miss Rate or False Negative Rate (FNR)	$FNR = FN / (FN + TP)$
Accuracy	Accuracy (ACC)	$ACC = (TP + TN) / (P + N)$

In the following pages the calculation of the confusion matrix, calculated for different types of networks and different phases are presented. In our case the “prediction” is the centre predicted to be central by their size and the “truth” the centres predicted to be central by the various network centrality measures, following the same thresholds already applied in the previous analyses. The confusion matrix allows to evaluate the predictive value of this model by considering the variables completely independent.

Etruria – River Networks

Betweenness Centrality

(For data, please visit www.cambridge.org/fulminante/EtruriaRiverNetworks_BetweennessCentrality)

Closeness Centrality

(For data, please visit www.cambridge.org/fulminante/etruriarivernetworks_closenesscentrality)

Normalised Degree Centrality

(For data, please visit www.cambridge.org/fulminante/etruriarivernetworks_NormalizedDegreeCentrality)

Etruria – Terrestrial Routes Network

Betweenness Centrality

(For data, please visit www.cambridge.org/fulminante/EtruriaTerrestrialRoutesNetwork_BetweennessCentrality2)

Closeness Centrality

(For data, please visit www.cambridge.org/EtruriaTerrestrialRoutesNetwork_BetweennessCentrality)

Normalised Degree Centrality

(For data, please visit www.cambridge.com/fulminante/EtruriaTerrestrialRoutesNetwork_NormalizedDegreeCentrality)

Latium vetus – River Networks

Betweenness Centrality

(For data, please visit www.cambridge.org/fulminante/LatiumVetusRiverNetworks_BetweennessCentrality)

Closeness Centrality

(For data, please visit www.cambridge.org/fulminante/latiumvetusrivernetworks_closenesscentrality)

Normalised Degree Centrality

(For data, please visit www.cambridge.org/fulminante/LatiumVetusRiverNetworks_NormalizedDegreeCentrality)

Latium vetus – Terrestrial Routes Network

Betweenness Centrality

(For data, please visit www.cambridge.org/fulminante/LatiumVetusTerrestrialRoutesNetwork_BetweennessCentrality)

Closeness Centrality

(For data, please visit www.cambridge.org/fulminante/LatiumVetusTerrestrialRoutesNetwork_ClosenessCentrality)

Normalised Degree Centrality

(For data, please visit www.cambridge.org/LatiumVetusTerrestrialRoutesNetwork_NormalizedDegreeCentrality)

Combined Centrality Indexes

However, the application of each traditional centrality index separately has some drawback, such as for example the low degree of heterogeneity in the results of the application of the degree centrality to spatial networks. Therefore, also new combined indexes have been created thanks to the collaboration with Sergi Lozano and Luce Prignano, respectively of the University of Tarragona and Barcellona¹¹. Taking as a starting point the degree centrality calculated on the road networks, which was the most successful, various combinations of indexes have been tried and the three best indexes have been selected. The first index (I₁): $I_1(N_i) = K_i^{road} + \widehat{C_B^{road}}(N_i)$ combines the degree centrality of the road network with the betweenness centrality of the road networks, normalised dividing by the maximum value it takes on the considered network: $C_B(N_i) = \frac{C_B(N_i)}{C_B^{MAX}}$. By adding the normalised betweenness centrality allows to distinguish, and therefore ordering, nodes with the same number of connections that cannot be properly ranked when considering the degree centrality alone. This index worked quite well but we still wanted to improve it by considering river networks as well.

The other two indexes add respectively the betweenness centrality of the river networks (I₂): $I_2(N_i) = K_i^{road} + \widehat{C_B^{road}}(N_i) + \widehat{C_B^{river}}(N_i)$ and the degree centrality of the river networks (I₃): $I_3(N_i) = K_i^{road} + \widehat{C_B^{road}}(N_i) + K_i^{river}$.

As it will be shown in the following section this further analysis, which includes information about the fluvial connections, gives results to be helpful only for the Bronze Age, while it is not useful, on average, for more recent ages. As with previous traditional network centrality indexes the correlation between this newly defined quantity and settlement size (an independent indicator of centrality also used in the previous exploratory analysis) has been explored through regression analysis. Finally, in order to provide a further validation of the original working hypothesis, we estimated how many centres would have been identified as primary if there was no information at all (random hypothesis); in this way it was possible to assess the relevance of knowledge about rivers and terrestrial routes embedded in our index.

APPENDIX D: DATA

Introduction

Here are presented the data used for analysis in the present work. The extensions of the sites have been generally calculated in GIS on regional maps with a resolution of 10.000 on the basis of the margins of the top of the hills and plateaux (often indicated by a concentration of contour lines), according to the rules suggested by the school of Pre-history and Proto-history: a settlement is assumed on a plateaux or hill both from material present on it or material displaced from the top and washed away on the sides or lowland at the foot of the hill. Open sites have been measured on their extension when available, or a minimal extension of 1 ha has been assumed in the absence of precise information or scatter material.

The geographical coordinates (WGS 84, 33 north) generally indicate roughly the middle of the settlement and they have been established using the regional 10.000 maps provided by Regione Lazio, as base, or sometime using the digital maps provided by Regione Lazio in the portal of Ministero dell'Ambiente (National Environment Institute). It ought to be noted that the geographical coordinates do not always indicate where the archaeological evidence has been found but where the settlement was likely to be, for example in the case of material washed away from the top of a hill, the area of the settlement has been calculated from the top of that hill. In addition, I would like to warn the reader that recently especially for Etruscan data I noticed that sometime there is a bug of 250 meters displacement, which I am not sure if is fully systematic or random and what it depends on. However, it does not have any effect on the analyses presented in this work which assume a much lower resolution. Sites have been also classified according to their sizes, on frequency diagrams (see text Chapter 4) but also taking into consideration the thresholds already

established in previous studies¹. Here the Latin and Etruscan GIS data have been combined in a single excel file with coordinates, sizes, and classification according to size established as said above and explained in more detail in Chapter 3.

How the networks have been constructed from a conceptual point of view has also been explained in Chapter 3. The predefined databases provided by Pajek (volume and tutorials online²) have been used to build the networks by using the x-y coordinates already established in GIS. Then the networks have been also converted in Gephi, which uses longitude and latitude, for further analyses and visualisation. The networks are presented as txt files of list of nodes nodes and edges. In fact, the files read and analysed by pajek can be saved also in this format. All the networks respectively for fluvial and terrestrial connection are presented separately for Latium vetus and Etruria. In fact, in this book the Latin and Etruscan networks have been considered as two separate regions, because of cultural differences. In a new work, in preparation, to be presented at the 2021 conference of the Society of American Archaeologists, they will be combined in a single unified network to be able to analyse the whole Tiber basin and compare fluvial communications system with the terre.

Latin and Etruscan GIS DATA:

(For the complete GIS Data, please visit www.cambridge.org/Fulminante/AppendixDGISData)

Pajek Network Data:

(For the complete Pajek Network Data, please visit www.cambridge.org/Fulminante/AppendixDPajekNetworkData)

Notes

Introduction

- 1 Fulminante 2014b.
- 2 For recent syntheses on the earliest phases of Rome, also within the wider context of *Latium vetus* see Carafa 2014a, 2014b, Fulminante 2018, Benedetti et al. 2020, Guidi, Fulminante, and Stammera 2021. These contributions do not change previous conclusions about this major shift in settlement development around Latial Period IIA2/IIB. However, they revise previous studies and new discoveries and define more in detail and in an articulated manner the very beginning of the early Iron Age (Latial Period IIA), where now a polynucleated centre with at least four foci (Palatine, Capitolium, Quirinal, Carinae) can be now identified rather than the previous traditional two foci around the Palatine and Capitoline hill.
- 3 Fulminante and Stoddart 2013, Fulminante et al. 2017b.
- 4 See e.g. Trombold 2011 (1991)b, Jenkins 2001, for the New World, Smith 2005b for Ancient States and Laurence 1999, Isaksen 2008 for the Roman world.
- 5 Nakoinz 2012b; 2012a; 2013b; 2013a, Fulminante 2020.
- 6 Latour 2005.
- 7 De Landa 2006 and with reference to scale: Marston, Jones, and Woodward 2005, Collinge 2006; particularly in archaeology, Harris 2017.
- 8 In particular I will refer to the recent book by Zuiderhoek 2016 which assesses previous and current debate on the ancient city and shows why it is still relevant today.
- 9 See, for example, Trigger 2003 and further discussion in Chapter 1. The recent Social Reactor Project at Colorado University is focusing on the relation between economic growth and urbanism from both an interdisciplinary theoretical perspective and methodological approach by applying settlement scaling theory to studies from the past and the present in order to find the common mechanisms underlying urbanisation and gain relevant understanding for our policy makers today www.colorado.edu/socialreactors/. I am currently

collaborating with this project and together with Scott Ortman, Luis Bettencourt and John W. Hanson we have edited a special research topic for Frontiers Digital Humanities on *Where Do Cities Come From and Where Are They Going To? Modelling Past and Present Agglomerations to Understand Urban Ways of Life*, www.frontiersin.org/research-topics/7460/where-do-cities-come-from-and-where-are-they-going-to-modelling-past-and-present-agglomerations-to-u.

- 10 Fulminante 2014b.
- 11 Stoddart 1988; Pacciarelli 2001, Fulminante and Stoddart 2013 and Cangemi 2016, also from a network perspective.
- 12 Torelli 1997 (1st ed. 1981), 183–278, Barker and Rasmussen 1998, 262–296.
- 13 Osborne 2005.
- 14 See, for example, Wilkins 1991, Malkin 2003, Fulminante 2014b with further discussion and references in Chapter 2.
- 15 See, for example, Menze and Ur 2012, Davies et al. 2014, Altawell and Palmisano 2015, Fulminante et al. 2017a, Filet 2017 with further discussion and references in Chapter 2.
- 16 See, for example, reviews of the weighted Laplacian matrix by Brughmans 2013, 2014 and collections such as, Knappett 2013b, Felder and Evans 2014 or Collar et al. 2015 with further references and discussion in Chapter 2.
- 17 On the principles and application of (Social) Network Analysis see the classic manuals such as Wasserman and Faust 2007 (1st ed. 1994) and De Nooy, Mrvar and Batagelj 2012; or the more accessible Scott 2000 and Knoke and Yang 2008 (1st ed. 1982)
- 18 See discussion in Fulminante et al. 2017, Prignano et al. 2019.
- 19 For example, see discussion in Prignano et al. 2017.
- 20 Herzog 2013b.
- 21 Verhagen et al. 2013, Verhagen, Joyce, and Groenhuijzen 2019, Verhagen, Nuninger, and Groenhuijzen 2019.
- 22 Fulminante et al. 2017b, Prignano et al. 2019.
- 23 Fulminante 2021.
- 24 Cangemi 2016.
- 25 Riva 2010, Stoddart 2020.

1 The Ancient City

- 1 See, for example, the recent synthesis by Mary Beard (2015) which has become a popular best-seller in non-fiction literature; note the quotations are from the review of her book by the *Wall Street Journal*.
- 2 Zuiderhoek 2016. Zuiderhoek declares that his discussion is on *urbanism* and not *urbanisation*. While I agree that the two topics are different, I do not think they can actually be separated in a discussion of the Ancient City. In fact, Zuiderhoek's book itself is full of references and themes related to the formation of the ancient city and/or urbanisation processes.

- 3 For a comparative perspective on polities organised in city-states see Nichols and Charlton 1997 and Hansen 1997a,b, 1998, 2000a, 2002, Hansen and Heine Nielsen 2004, and now also Yoffee 2015.
- 4 Fustel de Coulanges 1956 (1864).
- 5 Zuiderhoek 2016, 1–18; see also Yoffee and Terrenato 2015, including a detailed discussion of Fustel de Coulanges' work and its legacy in urbanism scholarship.
- 6 Zuiderhoek 2016, 9–10.
- 7 Weber 1921, 1978, 1958.
- 8 Zuiderhoek 2016, 11–12.
- 9 Finley 1981, 1999.
- 10 Zuiderhoek 2016, 12.
- 11 *Ibid*, 4–5.
- 12 De Vries 1984, Honenberg and Hollen Lees 1995 (1985), Storey 2006, Fletcher 1995.
- 13 Kostof 1991, cited by Zuiderhoek 2016, 4.
- 14 Wrigley 1967, Sharlin 1978, Cipolla 1994; for a contrasting perspective see Jedwab, Christiaensen, and Gindelsky 2017.
- 15 This hypothesis was originally advanced for the demographic growth of London during the Industrial Revolution in the classic work by McLaren 1978; it has been recently revived by Haydock et al. 2013 for Roman and Medieval Britain and deserves further investigation and testing especially for the first Urban Revolution of the ancient cities. In this sense I suggested in a recent contribution that Pre-Roman and Roman Italy would be an ideal context, given its long-term trajectory through different stages of urban evolution, to test this hypothesis. (See Fulminante and Müller-Scheeßel in press). In this sense as partially discussed by Zuiderhoek 2016, 74–75 besides mortality rates and migration, fertility rates have also to be taken into account as a key variable.
- 16 For this model see Weber's and Finley's theories discussed above and further discussion in Zuiderhoek 2016, chapter 3.
- 17 Zuiderhoek 2016, 6 and chapter 4. For a monumental approach to urbanism see Creekmore and Fisher 2014; with particular reference to Rome and central Italy see Cifani 2008, 2010, 2014, 2018. Contributions in Thomas and Meyers 2012 emphasise continuity between ephemeral wattle and daub huts of proto-historic Latium vetus and the later Archaic monumentalisation of Rome and the region. With reference to this approach, new technological developments, such as LIDAR, are favouring novel approaches, also within a comparative perspective, based on the complementarity and symbiotic relation between urbanism and anthropogenic landscapes, see for example, Chase and Chase 2016.
- 18 Zuiderhoek 2016, 78 and chapter 5.
- 19 *Ibid*, 94 and chapter 6.
- 20 For example, Polybius, *Historiae*, VI.56 or Titus Livius, *Historiae*, I.12.
- 21 Macchiavelli 2008 (1531).

- 22 Rüpke 2018, Urciuoli and Rüpke 2018.
- 23 Gonzalez-Ruibal and Ruiz-Galvez 2016.
- 24 Naglak and Terrenato 2019.
- 25 Engel 1884.
- 26 Peroni 1994, 1996.
- 27 Cardarelli 2011.
- 28 Fulminante 2014b.
- 29 *Ibid.*, 2018.
- 30 For example, Kostof 1991, Nichols and Charlton 1997, Hansen 2000a, 2002, Smith 2003, Trigger 2003, Marcus and Sabloff 2008, Yoffee 2015.
- 31 Smith 2003 quoted by Zuiderhoek 2016, 6–7.
- 32 *Ibid.*
- 33 Wirth 1938.
- 34 Most importantly Batty 2005.
- 35 Nakoinz 2017.
- 36 This section partially reproduces but also updates the discussion already presented in my book *Urbanisation of Rome and Latium Vetus from the Bronze Age to the Archaic Era* (Fulminante 2014b) and in my recent article on the Latin people (Fulminante 2018).
- 37 Fulminante 2014b, appendix 1.
- 38 di Gennaro and Peroni 1986, Peroni 1989, 2000, Stoddart and Spivey 1990, Bietti Sestieri 1997, 2010, Barker and Rasmussen 1998, Pacciarelli 2001, 119–136, di Gennaro and Guidi 2000, 2009, Vanzetti 2002, 2004, Bonghi Jovino 2005, Guidi 2006, 2008, 2010, Fulminante 2014b, 44–47, Marino 2015 and Stoddart in press.
- 39 di Gennaro and Peroni 1986, di Gennaro and Guidi 2000, Pacciarelli 2001, 128–136, Guidi 2008, 176–177.
- 40 di Gennaro and Guidi 2000, Pacciarelli 2001, 119–128, Guidi 2008.
- 41 Fulminante and Stoddart 2013.
- 42 Pacciarelli 2001b, 115–136 and Fulminante 2014b.
- 43 As, for example, has been noticed on the plateau of Cerveteri (Iaia and Mandolesi 2010), Veio (Patterson et al. 2004, in part. 15–16) and Gabii (Guaitoli 1981a,b).
- 44 As attested in the case of Gabii, Guaitoli 1981a,b.
- 45 Carandini and Carafa 2000.
- 46 Fontaine 2002–3, Moretti Sgubini 2006, Boitani, Biagi, and Neri 2008, Cataldi, Baratti, and Mordegla 2008, Fontaine and Helas 2016 with bibliography.
- 47 See, for example, Tarquinia (Bonghi Jovino 2008, 2010 with previous references) and Roma (Carandini 2007 and Carandini, Carafa, and Filippi in press).
- 48 Since the countryside is generally devoid of evidence for the earlier periods, it is generally believed that these new aristocratic settlements are generated by elites originated from the urban agglomerations; however, further research and

attention needs to be paid to reassess and understand anew the degree of real occupation or lack thereof of rural landscapes in pre- and proto-historic times.

- 49 De Santis 1997, Iaia and Mandolesi 2010, Fulminante 2014b, 47.
- 50 Carandini 2003 (2nd ed.), Carandini 2007, Cifani 2014, Hopkins Fulminante 2014b, 249–260, 2014.
- 51 Fulminante 2003, Seubern 2005, De Santis 2005, Guidi and Santoro 2008, Fulminante and Stoddart 2013.
- 52 Bietti Sestieri and De Santis 2003, De Santis 2011.
- 53 Pacciarelli 2001b, Fulminante 2003, more nuanced Vanzetti 1996, 175 and Vanzetti, 2006.
- 54 De Santis 2011, 44–51.
- 55 Colonna 1977, Bartoloni, Nizzo, and Taloni 2009.
- 56 Bietti Sestieri 1992.
- 57 Bedini 1980, 1985, 1990, 1992, 1994.
- 58 Smith 2008 (1st ed. 2006).
- 59 Motta and Terrenato 2006, Terrenato 2010, Yoffee and Terrenato 2015, Naglak and Terrenato 2019.
- 60 Nijboer 1998.
- 61 Rasmus Brandt 2001.
- 62 *Ibid*, 408–409.
- 63 *Ibid*, 410.
- 64 *Ibid*, 411.
- 65 Nijboer 1998, 242–246.
- 66 *Ibid*, 204.
- 67 *Ibid*, 159.
- 68 Bietti Sestieri 1992, 94.
- 69 *Ibid*, Colonna 1988, 297.
- 70 Colonna 1988, 298–299.
- 71 Iaia 2005, 270.
- 72 Gleba 2008, Lipkin 2012, Gleba and Laurito 2017.
- 73 Gleba 2007, 2008, 2009, Gleba and Laurito 2017.
- 74 De Santis 2011, 33.
- 75 Gleba 2007, 2008, 43–57, 2009.
- 76 Meyers 2013.
- 77 Gleba 2008, 189–190, Lipkin 2012, 113.
- 78 Gleba 2007, 75, 2008, 163–165.
- 79 Van Joolen 2002, 191.
- 80 *ibid*, 2002, 2003.
- 81 Costantini and Giorgi 2001, 245; Fiorentino et al. 2000, for evidence of olive cultivation in the Abruzzo during the Bronze Age.
- 82 Torelli 1996 for the interpretation of this object.
- 83 Motta 2002.
- 84 Minniti 2012.

- 85 For a more nuanced interpretation of pigs in pre-Roman and Roman Italian contexts, see also Trentacoste 2015.
- 86 Guidi 1981, 1989–1990, 2000, 2004.
- 87 *Ibid*, Carafa 2014a, 37.
- 88 Zeggio 2000.
- 89 Albertoni 2000.
- 90 Filippi 2004, Carandini, Carafa, and Filippi in press.
- 91 Bietti Sestieri 2010, 281.
- 92 Guidi 2000, 2004.
- 93 Smith 2000, 84–85.
- 94 Pallottino 1991, 47.
- 95 Bradley 2000a,b.
- 96 Bradley 2000b, 117.
- 97 Peroni 1994, 1996.
- 98 Ampolo 1976–1977, 1981, 1987.
- 99 Guidi, Pascucci, and Zarattini 2002, 6.
- 100 Cifani 2002, 2003.
- 101 di Gennaro, Schiappelli, and Amoroso 2004.
- 102 Torelli 1988, 54–55, quoted by Bradley 2000b, 111.
- 103 See, for example, Ampolo et al. 1980, in particular, 113 and 169, even though previous developments toward social differentiation are not fully denied; see also Strom, 1971, 1984, Pallottino 1984, 213 and 307, Rathje 1984, 1990, 1995, Harris 1989, Pallottino 1991, 55–56. While admitting important pre-existent local developments (settlement centralisation, emerging of embryonic social differentiation and craft specialisation), Ridgway 1992, 129–144, suggests that the impact of external influences should not be underestimated. See also various contributions in Damgaard Andersen, Horsnae, and Rathje 1997. Recently, Forsythe 2005, 31–58 again emphasised the ‘extraordinary impact’ that Phoenician and Greek settlements and commercial activity in the Mediterranean had upon the people of Italy. Rasmussen 2005, 72 ff. and 82–83, seems to agree with the ‘Orientalist’ point of view, but only implicitly. More cautiously, Cornell 1995, 87–92 and Smith 2005, 102, while emphasising the importance of external influences, acknowledge also the existence of significant independent local developments toward higher complexity. Finally, as pointed out by Guidi 2006, it ought to be noted that, outside Italy, diffusionist ideas also seem to have been adopted by many prehistorians, such as, for example, Champion et al. 1984, 259 or Sherratt 1993, 93.
- 104 See, for example, di Gennaro 1986, di Gennaro and Peroni 1986, Peroni 1989, 2000, Bietti Sestieri 1997, but only with reference to Etruria, from which urbanisation would have passed to nearby Latium vetus; or Stoddart and Spivey 1990, 40 ff., Barker and Rasmussen 1998, 84 ff., di Gennaro and Guidi 2000, Guidi 1998, 2006 and Pacciarelli 2001a.
- 105 See previous partial discussion in Fulminante 2014b.

2 Transportation Infrastructures

- 1 This section develops and expands some ideas originally published a few years ago in a thematic volume edited by Sarah Evans and Kathrin Felder on *Social Network Perspectives in Archaeology* (Fulminante 2014a), expanded and updated with current bibliography.
- 2 See below and Section 2.2.
- 3 Sherratt 1993a,b,c, Sherratt and Sherratt 1993; on this see also Knappett 2013a, 5–6.
- 4 Sherratt 1993 a, b, Sherratt and Sherratt 1993, on this see also Peroni 1979.
- 5 Sherratt 1993a,b, Sherratt and Sherratt 1993; For a combination of world system theory and network perspective applied to Prehistoric Europe see also Harding 2013. For an application of world system theory to world history, taking also into consideration globalisation theory and the role of ‘spatial links’ see Grinin 2017, Grinin and Korotayev 2013.
- 6 Rowland et al 1987.
- 7 Renfrew and Cherry 1986.
- 8 Renfrew and Bahn 2004 (1st ed. 1991), 389–391.
- 9 Stein 1999, 169. But see also Philip L. Kohl, “1 – the Use and Abuse of World Systems Theory: The Case of the Pristine West Asian State,” in *Advances in Archaeological Method and Theory*, ed. Michael B. Schiffer (San Diego: Academic Press, 1987) and Kent G. Lightfoot and Antoinette Martinez, “Frontiers and Boundaries in Archaeological Perspective,” *Annual Review of Anthropology* 24, no. 1 (1995).
- 10 Stein 1999, 171.
- 11 Thomas 1991.
- 12 Van Dommelen 2006.
- 13 Horden and Purcell 2000, Cunliffe 2008, Broodbank 2013.
- 14 Hodos 2017, see also Grinin and Korotayev 2013, Grinin 2017.
- 15 See Wilkins 1991, Fulminante 2014b with discussion of previous works and more specifically Knappett 2017.
- 16 Hodos 2017, Sherratt 2017 on the Bronze and Iron Age Mediterranean; see also for similar perspective and ideas in the New World Mills and Peebles 2019.
- 17 Grimes 2017.
- 18 This section gives a brief overview of network analysis applications within the archaeological field. For recent reviews of state of the art see also, Brughmans 2013, 2014, Fulminante 2014a, Mills 2017.
- 19 Knoke and Yang 2008 (1st ed. 1982), 6–9.
- 20 Estrada 2012.
- 21 Travers and Milgram 1969.
- 22 For example, Barabási 2003, Watts 2003a, b, Barabási and Oltvai 2004, Newman, Barabási, and Watts 2006.
- 23 See Fulminante 2012, 2–3 with bibliography.
- 24 Dicks 1972, Hutchinson 1972, Langton, Hindle, and Dicks 1972.
- 25 Pitts 1965, 1978/1979.
- 26 Rothman 1987.

- 27 Irwin-Williams 1977, Irwin 1983.
- 28 For example Santley 1991, Hage and Harary 1991, 1996.
- 29 For example, Broodbank 2000, Jenkins 2001, Mackie 2001, Nuninger 2002, 2003, Nuninger 2002, 2003, Classen 2004, 2008, Classen and Zimmerman 2004, Orser Jr. 2005, Graham 2006a, b, c, 2007, 2009, Moore 2007, Sindbaek 2007a,b, 2013, Isaksen 2008, Evans, Knappett, and Rivers 2008, 2009, 2013, Fulminante 2012, Brughmans 2013, 2014, Mizoguchi 2013, Verhagen et al. 2013, Da Vela 2014–15, Prignano et al. 2019, Donnellan 2015, Donnellan 2019, Mills 2016, Mills, Clark, and Peebles 2016, Paliou and Bevan 2016, Filet 2017, Brughmans and Brandes 2017, Prignano, Morer, and Diaz-Guilera 2017, Prignano et al. 2017, Mazzuccato 2019, Verhagen, Joyce, and Groenhuijzen 2019, Verhagen, Nuninger, and Groenhuijzen 2019, Mills and Peebles 2019, Nakoinz, Bilger, and Matzig 2020.
- 30 Lock and Pouncett 2007, Knappett 2013b, Felder and Evans 2014, Collar et al. 2015, Brughmans, Collar, and Coward 2016, Leidwanger and Knappett 2018, Donnellan 2020.
- 31 Mackie 2001, Graham 2006a, Ruffini 2008, Blake 2014, Collar 2013, Mazzilli 2019.
- 32 For current approaches and updates see also the activity of the Connected Past Committee <https://connectedpast.net/> and Historical Network Research Group <http://historicalnetworkresearch.org/>.
- 33 Knappett 2013a, 6.
- 34 Childe 1950, 1925.
- 35 Classic works that delineate this trajectory are the controversial *Black Athena* trilogy (Bernal 2006 [1987, 1991]), or the classic work on Greek art by Sarah Morris: *Dedalus* (Morris 1995).
- 36 For this perspective, see, for example, Ridgway and Ridgway 1979, Ridgway 1992, 2000.
- 37 Cunliffe and Fernandez Castro 1995, 1999.
- 38 Van Dommelen 1997.
- 39 Whitehouse and Wilkins 1989.
- 40 See, for example, Guidi 1982, Stoddart and Spivey 1990, Pacciarelli 1991, 1994, 2001; Barker and Rasmussen 1998; Peroni 2000, and more recently, Guidi 2006, 2008, 2010, Pacciarelli 2010, 2017, Fulminante 2014b, Stoddart 2020.
- 41 Naso 2000, 2006.
- 42 Fulminante and Stoddart 2013, Fulminante 2014b, 243–246; on a first wave of ‘westernisation’ during the 13th century BC see Iacono 2013; see also other contributions in Sabatini and Alberti 2013.
- 43 Renfrew and Cherry 1986; and see Section 1.1.
- 44 Wilkins 1991.
- 45 Horden and Purcell 2000, Morris 2003, Cunliffe 2008, Broodbank 2013, Hodos 2009, 2017.
- 46 Braudel 1949 (1966).
- 47 Osborne 2005.
- 48 See also the definition of the ‘shining sea’ in Broodbank 2013, 446–448 with figure 9.1.

- 49 Malkin 2011, 3–5, with figures 1.2 and 1.3.
- 50 See, for example, Osborne 2005, Malkin 2011, Fulminante 2014b: 245, Bintliff 2016; Hodos 2017, 2020.
- 51 Fulminante 2014b, 245 with references; Bintliff 2016.
- 52 Childe 1925, 342–343.
- 53 The network model has been applied in the first decade of the third millennium to ancient state civilisations in general (L.M. Smith 2005), Iron Age France (Nuninger 2002, 2003), Iron Age Britain (Moore 2007) and Viking Scandinavia (Sindbaek 2007a).
- 54 Rihll and Wilson 1991.
- 55 Rihll and Wilson 1991, 61–63.
- 56 Bevan and Wilson 2013.
- 57 Evans, Knappett, and Rivers 2008, 2009, 2013.
- 58 Filet 2017.
- 59 Paliou and Bevan 2016.
- 60 Blake 2013.
- 61 Da Vela 2014–2015.
- 62 Mazzuccato 2019.
- 63 Cangemi 2016.
- 64 Baroloni 1987.
- 65 Fulminante and Unavane 2020.
- 66 Donnelan 2019.
- 67 See Fulminante 2022.
- 68 *Ibid.*, 2022.
- 69 Cangemi 2016.
- 70 Renfrew and Cherry 1986.
- 71 Hansen 2000b.
- 72 For example, Hodder 1972, 1979a,b, Paynter 1982.
- 73 Johnson 1980; Johnson 1981.
- 74 Kowalewski 1982; Kowalewski et al. 1983.
- 75 Falconer and Savage 1995.
- 76 Drennan and Peterson 2004.
- 77 Crema 2015.
- 78 Judson and Hemphill 1981, Guidi 1985, Fulminante and Stoddart 2013, Fulminante 2014b, Stoddart 2020.
- 79 Marzano 2011.
- 80 Tacoma 2006.
- 81 Hanson 2011.
- 82 *Ibid.*, 2016.
- 83 Fulminante and Hanson forthcoming.
- 84 Rihll and Wilson 1991, Broodbank 2000, Menze and Ur 2012, Evans, Knappett, and Rivers 2009, 2013, Bevan and Wilson 2013, Davies et al. 2014, Altawell and Palmisano 2015, Paliou and Bevan 2016.

- 85 That has been partially considered in Fulminante 2022 and will be further analysed in future work to provide a complementary cultural perspective to the approach taken in this book.
- 86 For example, Trombold 2011 (1991) for the New World and Laurence 1999 for the Roman world.
- 87 Nakoinz 2012b, 2012a, 2013b, 2013a.
- 88 Latour 2005.
- 89 De Landa 2006 and with reference to scale: Marston, Jones, and Woodward 2005, Collinge 2006, particularly in archaeology, Harris 2017.
- 90 Marston et al. 2005.
- 91 For example, emergence of ‘urbanism’, see Earle 2011(1991) and Lay 1992 and/or ‘Romanisation’, see Laurence 1999.
- 92 Fulminante 2020b.
- 93 Barabási 2003, 2009.
- 94 On assemblage theory and history interpreted as interwoven scales rather than scales hierarchically constituted, see Harris 2017.
- 95 Batty 2003, Bikoulis 2012 and discussion with particular reference to paths and movement by Verhagen, Nuninger, and Groenhuijzen 2019
- 96 For example, Ortnan et al. 2016.
- 97 See for example contributions in Koschick 2004 or Rathmann 2006.
- 98 See for example Dorsey 1991, Kolb 2004, Carreras and De Soto 2010, Nakoinz 2012b, Blöck and Beck 2017.
- 99 McCormick 2002; Adams 2012.
- 100 Chevallier 1976.
- 101 Taylor 1979.
- 102 Crumley and Marquadt 1987.
- 103 Purcell 1990.
- 104 Mattingly 1997.
- 105 Laurence 1999.
- 106 Nakoinz 2012a,b.
- 107 Filet 2017.
- 108 Potter 1979.
- 109 Boitani 1985.
- 110 Izzet 2007.
- 111 Tuppi 2014.
- 112 Fulminante 2012.
- 113 Santley 1991, Chevallier 1976.
- 114 Jenkins 2001.
- 115 Smith 2005.
- 116 Hendrickson 2010.
- 117 Trombold 2011 (1991).
- 118 Menze and Ur 2012.

- 119 Davies et al. 2014.
- 120 Malkin 2011.
- 121 For example, De Soto and Carreras 2013, Groenhuijzen and Verhagen 2016, Filet 2017, Volkmann 2017, Faupel 2018, Faupel and Nakoinz 2018.
- 122 For example, Fulminante et al. 2017; Prignano et al. 2019; Matteazzi 2017.
- 123 See also recent projects such as ORBIS by Stanford University, <http://orbis.stanford.edu/orbis2012/>, or the New Transhumance project in Toscana; Pizziolo et al. 2016 or Mercator E-Project in Spain <http://fabricadesites.fesh.unl.pt/mercator-e/>.
- 124 Following my recent Fellowships at Durham with Rob Witcher (IAS 2018) and Kiel with Oliver Nakoiz (DfG 2019), together with MA advisor Paolo Carafa and my PhD supervisor Simon Stoddart, we have developed a comparative perspective to study the origin of the Roman road network at the centre (Etruria and Latium) and at the periphery of the Empire (south-western Germany) that hopefully will be further developed to include other regions of Europe, such as Spain (Pau De Soto), Turkey (Dries Daems), Greece (Emeri Farinetti) etc.
- 125 Fulminante 2012.
- 126 Fulminante, Lozano, and Prignano 2016.
- 127 Fulminante 2020b, 2021, Fulminante et al. 2020.
- 128 Fulminante et al. 2017, Prignano et al. 2019.
- 129 Knappett 2013a, 4–6.
- 130 See discussion in Section 2.2.
- 131 *Ibid.*
- 132 See above discussion in Section 2.3.

3 Data and Methodology

- 1 Gell 1934, Nibby 1837, Dennis 1848.
- 2 Nissen 1883–1902, Lanciani 1909, Solari 1915–20.
- 3 *Carta Archaeologica del Territorio di Roma*, prepared in the 1920s–30s but only published in the 1960s (Lugli 1962).
- 4 For example: Giuliani and Quilici 1964, Giuliani 1966, 1970, Giuliani and Quilici 1964 and other subsequent works of the Institute of Topography of the University of Rome La Sapienza and the volumes of the *Forma Italiae* published by them; or Quilici 1974 and other volumes of the *Latium vetus* series, see below.
- 5 Obviously and mostly the famous John Bryan Ward-Perkins, director of the British School of Rome and of the important South Etruria Project. For a deep and detailed discussion of the work of this scholar, within the wider context of landscape archaeology, see Stoddart 2000 and Smith 2017.
- 6 Ward Perkins 1961, 1962.
- 7 Potter 1979.
- 8 Bietti Sestieri and Sebastiani 1986, Bietti Sestieri 1989.

- 9 For example, di Gennaro 1986, 1988, Guidi 1986a,b, and more recently Pacciarelli 2001b, Schiappelli 2008, Barbaro 2010, Alessandri 2007, 2013.
- 10 Arnoldus Huyzendveld et al. 1995.
- 11 For some publications derived from the Pontine Plain Project see, for example, Attema 1993, Attema et al. 2002, Attema et al. 2007, and recently De Haas 2011, while a full publication is in preparation; for the Nettuno Survey see Attema, de Haas, and Tol 2010.
- 12 For results of this project see Patterson 2004, Cascino, Di Giuseppe, and Patterson 2012, and Patterson, Di Giuseppe, and Witcher 2020.
- 13 Guidi 2003, Guidi, Rioda, and Santoro 2008.
- 14 Carandini 2012.
- 15 www.archeositarproject.it/
- 16 Fulminante 2014b.
- 17 Alessandri 2007, 2013.
- 18 di Gennaro 1986.
- 19 Barbaro 2010.
- 20 Schiappelli 2008.
- 21 Iaia and Mandolesi 2010.
- 22 Rendeli 1993.
- 23 For example, the Proceedings of the biannual conference *Preistoria and Protostoria in Etruria*.
- 24 For example, Della Fina and Pellegrini 2013.
- 25 For a reconstruction of the paleo river of the Tiber especially with reference to the modern and ancient coastline, see Alessandri 2007, 2013 with previous references.
- 26 Colonna 1977.
- 27 Although important work on Orientalising and Archaic road cuts has been done by Tuppi 2014.
- 28 Potter 1979, 1985.
- 29 Zifferero 1995, 2002a,b.
- 30 Tartara 1999.
- 31 Brocato 2000.
- 32 Enei 2001.
- 33 Bonghi Jovino 2008.
- 34 Schiappelli 2008.
- 35 See, for example, volumes *Forma Italiae*.
- 36 Müller 1904.
- 37 Trombold 2011 (1991).
- 38 To the work cited as used in this study the work by Wetter 1962 has to be added; it was unfortunately overlooked at the stage of the reconstruction of the networks and analyses.
- 39 See below further discussion in Section 3.2 on methodology.
- 40 For a first application limited to Latium vetus see Fulminante 2012.
- 41 Pitts 1965, 1978/1979, Hutchinson 1972, Langton, Hindle, and Dicks 1972.

- 42 Graham 2006b, Isaksen 2008.
- 43 di Gennaro 1986, Pacciarelli 2001a, Barbaro 2010.
- 44 On this see also previous discussion in Fulminante 2012b.
- 45 Fulminante, Lozano, and Prignano 2016.
- 46 See detailed description of the methodology from a mathematical point of view in Prignano et al. 2019.
- 47 Herzog 2013a,b.
- 48 See, for example, Müller 1904 but also traditional approach in topographic and landscape archaeology in Italy, such as Potter 1979, or in the archaeology of the New World Trombold 2011 (1991).
- 49 Nakoinz 2012b, Nakoinz and Knitter 2016, Faupel and Nakoinz 2018
- 50 Marwick, Boettiger, and Mullen 2017.
- 51 Tuppi 2014.

4 Network Analysis Centrality Indexes

- 1 di Gennaro 1986b, di Gennaro and Barbaro 2008, Barbaro 2010.
- 2 Guidi 1985, Pacciarelli 2001b.
- 3 Fulminante 2012a.
- 4 Knoke and Yang 2008 (1st ed. 1982), 68.
- 5 Knoke and Yang 2008 (1st ed. 1982), 68–69; but see also the seminal papers by Freeman 1977 and White and Borgatti 1994
- 6 Knoke and Yang 2008 (1st ed. 1982), 68.
- 7 Sabidussi 1966.
- 8 Beauchamp 1965 quoted in Knoke and Yang 2008 (1st ed. 1982), 66.
- 9 Knoke and Yang 2008 (1st ed. 1982), 63–64.
- 10 These indexes are discussed in more details in Fulminante, Lozano and Prignano 2016a.
- 11 See Fulminante and Stoddart 2012 and Fulminante 2014b with previous references, especially Pacciarelli 2001 and Guidi 1985.
- 12 The pomerium, the limit of the city, had been inaugurated with a plough by Romulus in an Etruscan rite, and original encompassed only the Palatine Hill, within the eight-century earthen fortification wall, superimposed on the furrow made by the plough.
- 13 de Haas 2017, Witcher 2017.

5 Network Analysis Efficiency Indexes

- 1 Boccaletti et al. 2006.
- 2 For the implications of this assumption and for further potential development calculating the cost of distance with least-cost path analysis and/or other methods see discussion in Section 3.2 on methodology.

- 3 Latora and Marchiori 2001, 288.
- 4 van Mieghem 2012.
- 5 Barrat et al. 2004.
- 6 Vragović, Louis, and Díaz-Guilera 2005.

6 Multi-scale Analysis Based on Least-Cost Paths

- 1 Fisher 2003, Batty 2003, Bikoulis 2012, Herzog 2013a, Verhagen, Nuninger, and Groenhuijzen 2019.
- 2 Herzog 2013b.
- 3 Tyler et al. 2002.
- 4 Rothenberg 2014.
- 5 *Ibid.*, 2014, p.16.
- 6 Di Giuseppe, Patterson, and Witcher 2020
- 7 <http://comparativesurveyarchaeology.org/>
- 8 Rothenberg 2014.
- 9 These ideas emerged from discussions with Rob Witcher at Durham, during my IAS Fellowship at the College of St Hild and Bede, Michaelmas Term 2018.
- 10 For further details and a full overview of the capabilities and limitations of this tool see the online material provided by ArcGIS at <http://desktop.arcgis.com/en/arcmap/latest/tools/spatial-analyst-toolbox/cost-connectivity.htm> (accessed 27-09-2018).
- 11 Quilici Gigli 1986, Cifani 2003.
- 12 Freeman 1977, 1979
- 13 de Haas 2017.
- 14 This road in particular, right in the middle of the peninsula, seems to be the most important route across Italy in the Roman era, according to the analysis by de Haas 2017.
- 15 Alessandri 2007, 2013.
- 16 On the importance of these routes, see Bietti Sestieri 1992 and Alessandri 2016.
- 17 Fulminante 2019.
- 18 Filippi 2005.
- 19 Coarelli 1988-1992, 1988, Torelli 1993
- 20 Russell 2014: 482.
- 21 *Ibid.*
- 22 *Ibid.*
- 23 Russell 2014: 485.
- 24 Cassius Dio, *Historia Romana*, 54.8, 4; Plutarch, *Galba* 24.4; Pliny, *Naturalis Historia*, 3.66; Tacitus, *Historiae* 1.27; Suetonius, *Otho* 6.2.; Alanus ab Insulis, *Liber parabolarum*, 591: 'Mille viae ducunt homines per saecula Romam'.
- 25 On the pre-existence of consular routes, see also Jarva and Tuppi 2016, 132–133 with further references therein at notes 99 and 133.
- 26 Ward Perkins 1962 and Potter 1979: fig. 14, p.61.

- 27 Kuusisto and Tuppi 2009, Jarva et al. 2013.
- 28 Jarva and Tuppi 2016: 133.
- 29 Ward Perkins 1962: 398.
- 30 *Ibid.*
- 31 Cocchi Genick et al. 1995.
- 32 See pioneering work by Pallottino 1981, 1984, 1991 and more recently Bradley, Isayev, and Riva 2007 and Farney and Bradley 2017
- 33 Blake 2014.
- 34 Stek 2014.
- 35 Again some of these ideas were developed in conversation with Rob Witcher.

7 Modelling

- 1 Albert and Barabási 2002, Boccaletti et al. 2006.
- 2 Prignano et al. 2019.
- 3 Vragović, Louis and Díaz-Guilera 2005.
- 4 It is usual for network scientists to refer to the networks built on the bases of empirical observations as ‘real networks’ to differentiate them from ‘artificial’ or ‘model generated’ graphs. However, in the context of archaeological studies, we preferred the term ‘empirical networks’.
- 5 Albert and Barabási 2002.
- 6 For an exhaustive discussion of the motivations and implications of this choice, check the previous publication by the author and colleagues, Prignano et al. 2019.
- 7 Prignano et al. 2019 and Fulminante et al. 2017 for Southern Etruria and Latium vetus respectively.
- 8 Waugh (2000) quoted in
- 9 Different types of least-cost path networks are discussed and reviewed by Herzog 2013a.
- 10 Fulminante 2012b.
- 11 Morer et al 2020, table 1.
- 12 It ought to be noted here that Gabii is another primary and very important site in Latium vetus that shows clearly some special characteristic as will be shown in an ego-network approach that will be presented in another work; Satricum is also rather important but located in a more peripheral position; while only some sporadic Iron Age materials are known from Guadagnolo.
- 13 Prignano et al. 2019.
- 14 Renfrew 1986, Renfrew and Cherry 1986 and Verhagen 2015.
- 15 Note that the average weighted degree remains the same both for empirical networks and those created by the models because it is based on the total length of all links divided by the number of settlements, and these are both fixed input points in all the models.

- 16 This very important feature of the Roman policy has been observed a few years ago for the Archaic period by Ampolo 1976–1977, Ampolo 1981, Ampolo 1987 and more recently has been recognised as a key feature of the Roman success through its all long-term trajectory by Beard 2015.
- 17 Fulminante and Stoddart, 2012.
- 18 Prignano et al. 2019.

Conclusions

- 1 Zuiderhoek 2016.
- 2 www.frontiersin.org/research-topics/7460/where-do-cities-come-from-and-where-are-they-going-to-modelling-past-and-present-agglomerations-to-u.
- 3 See, for example, Zuiderhoek 2016, p.6–7.
- 4 See, for example, Ortman et al. 2016, Ortman and Coffey 2017, Hanson and Ortman 2017 and further discussion in Cabaniss 2019.
- 5 Smith and Lobo 2019
- 6 Bettencourt and Lobo 2019
- 7 For an archaeology more relevant for our world today, see also discussion in Ortman 2019.
- 8 Wilkins 1991.
- 9 Osborne 2005.
- 10 Constantakopoulou and Panagopoulou 2009, Malkin 2011.
- 11 Fulminante 2014a,b.
- 12 Broodbank 2000.
- 13 Evans, Knappett and Rivers 2008, 2009, 2013.
- 14 Paliou and Bevan 2016.
- 15 Nuninger 2002, 2003.
- 16 Sindbæk 2007a,b, 2012, 2013, 2015.
- 17 Menze and Ur 2012
- 18 Filet 2017.
- 19 Nakoinz 2012a,b, 2013a,b, 2017, Faupel and Nakoinz 2018.
- 20 De Soto and Carreras 2013, De Soto 2018.
- 21 Matteazzi 2017.
- 22 Groenhuijzen and Verhagen 2016.
- 23 <http://orbis.stanford.edu/orbis2012/>.
- 24 Pizziolo et al. 2016.
- 25 <http://fabricadesites.fcsh.unl.pt/mercator-e/>.
- 26 Fulminante 2012b, Fulminante, Lozano, and Prignano 2016, Fulminante et al. 2017, Prignano et al. 2019.
- 27 Rajala 1999, 2002.
- 28 Fulminante 2012a.
- 29 Similar conclusion has also been reached by Verhagen et al. 2013.

- 30 See, for example, Herzog 2013b.
- 31 See, for example, discussion and one potential solution in Faupel 2018, Faupel and Nakoinz 2018 and the complete and exhaustive review of modelling pathways and movement networks by Verhagen, Nuninger and Groenhuijzen 2019.
- 32 Stoddart 1990, Stoddart in press, for Etruria; Fulminante 2014b for *Latium vetus* and Fulminante and Stoddart 2013 for a comparative perspective.
- 33 Beard 2015.

Appendix A: Mathematical Explanations and Calculations for Chapter 5

- 1 Boccaletti et al. 2006.
- 2 For the implications of this assumption and for further potential development calculating the cost of distance with least-cost path analysis and/or other methods see discussion above in Section 3.2 Methodology.
- 3 Latora and Marchiori 2001, 288.
- 4 Vragović, Louis, and Díaz-Guilera 2005.
- 5 van Mieghem 2012.
- 6 Barrat et al. 2004.
- 7 Vragović, Louis, and Díaz-Guilera 2005.

Appendix B Modelling from Chapter 7 Step-by-Step

- 1 Barrat et al. 2004.
- 2 Albert and Barabási 2002.
- 3 Vragović, Louis, and Díaz-Guilera 2005.
- 4 Barrat et al. 2004.
- 5 Prignano et al. 2019.
- 6 Renfrew 1986, Renfrew and Cherry 1986 and Verhagen 2015.

Appendix C: Mathematical Explanations and Calculations for Chapter 4

- 1 Knoke and Yang 2008 (1st ed. 1982), 68.
- 2 Knoke and Yang 2008 (1st ed. 1982), 68–69; but see also the seminal papers by Freeman 1977 and White and Borgatti 1994
- 3 Knoke and Yang 2008 (1st ed. 1982), 68.
- 4 Sabidussi 1966.
- 5 Knoke and Yang 2008 (1st ed. 1982), 65.
- 6 Beauchamp 1965 quoted in Knoke and Yang 2008 (1st ed. 1982), 66.
- 7 Knoke and Yang 2008 (1st ed. 1982), 63.
- 8 Knoke and Yang 2008 (1st ed. 1982), 63.

- 9 Wasserman and Faust 2007 (1st ed. 1994), 179 quoted in Knoke and Yang 2008 (1st ed. 1982), 63.
- 10 Knoke and Yang 2008 (1st ed. 1982), 63-64.
- 11 These indexes are discussed in more details in Fulminante, Lozano, and Prignano 2016a.

Appendix D: Data

- 1 Guidi 1985, di Gennaro 1986, Pacciarelli 2001, Barbaro 2010.
- 2 de Nooy, Mrvar, and Batagej 2005.

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The trajectory of Rome from a small village in *Latium vetus*, to an emerging power in Italy during the first millennium BC, and finally, the heart of an Empire that sprawled throughout the Mediterranean and much of Europe until the 5th century CE, is well known. Its rise is often presented as inevitable and unstoppable. Yet the factors that contributed to Rome's rise to power are not well understood. Why Rome and not Veii? In this book, Francesca Fulminante offers a fresh approach to this question through the use of a range of methods. Adopting quantitative analyses and a novel network perspective, she focuses on transportation systems in Etruria and Latium Italy from ca. 1000–500 BC. Fulminante reveals the multiple factors that contributed to the emergence and dominance of Rome within these regional networks, and the critical role they in the rise of the city and, ultimately, Roman imperialism.

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